



LIVESTOCK PRODUCTION IN THE SUBHUMID ZONE OF WEST AFRICA:

A REGIONAL REVIEW



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LIVESTOCK PRODUCTION IN THE
SUBHUMID ZONE OF WEST AFRICA:
A REGIONAL REVIEW

This One



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ABSTRACT

This report on livestock production in the subhumid zone of West Africa is based on the results of a symposium held in Kaduna, Nigeria in March 1979, co-sponsored by the International Livestock Centre for Africa and the National Animal Production Research Institute. A definition of the zone is given, followed by a brief description of the environment and the Fulani pastoralists who own most of the livestock. The fodder and animal resources of the zone are then described, followed by sections on tsetse-transmitted trypanosomiasis and other animal diseases, and concluding with an analysis of land-use and development strategies. The report is based largely on experience in Nigeria with ruminant livestock production.

KEY WORDS

livestock production, subhumid zone, West Africa, animal health, fodder production, *Glossina* spp.

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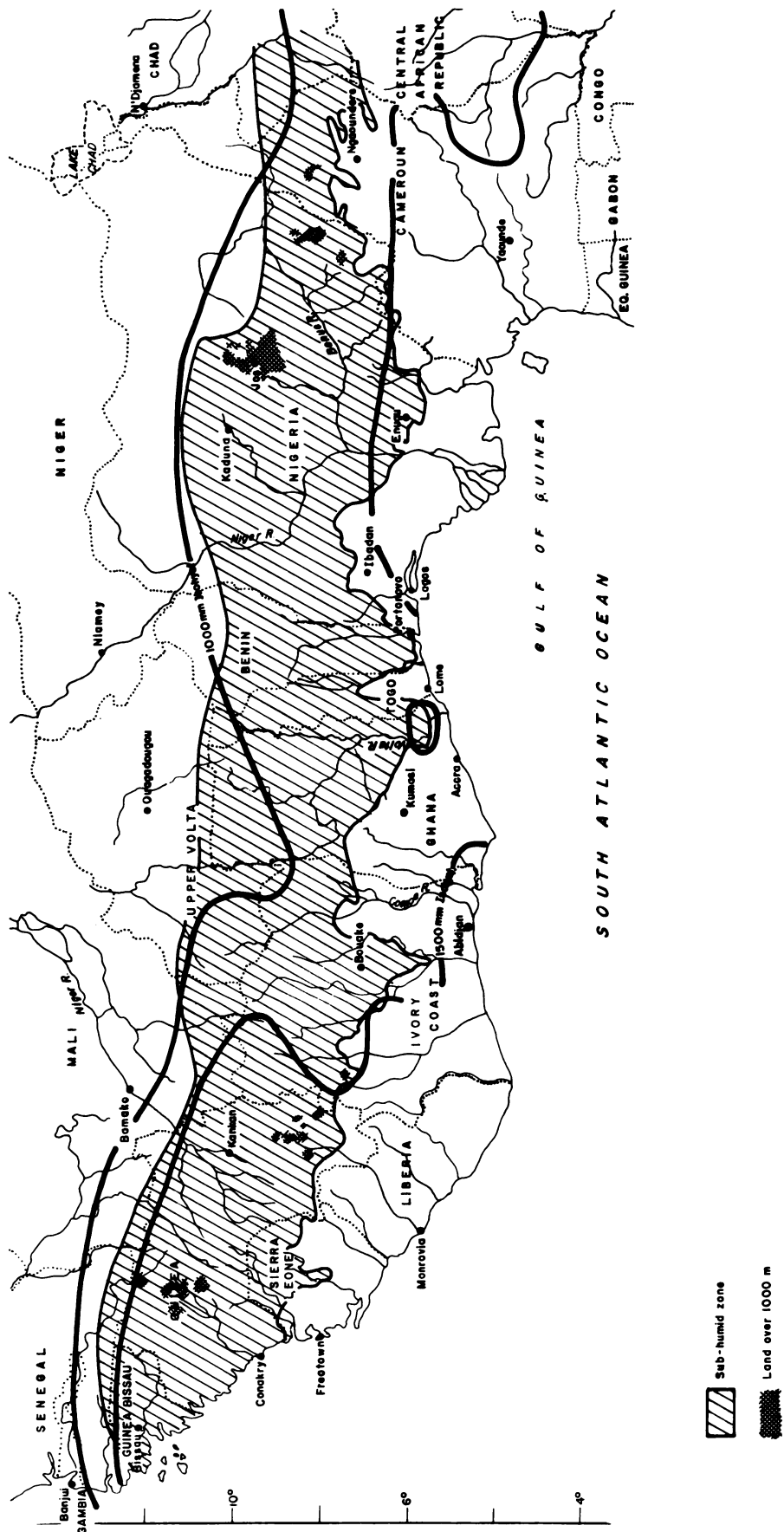
THE ZONE

The subhumid zone of West Africa forms a continuous belt, extending roughly parallel to the Equator between latitudes 6° and 12° N, including portions of Senegal, Guinea-Bissau, Guinea, Sierra Leone, Mali, Ivory Coast, Upper Volta, Ghana, Togo, Benin, Nigeria and Cameroon, as shown in Figure 1. This designation includes most of the northern and southern Guinea savannas plus the derived savanna zone (forest savanna mosaic), as defined by Keay (1959) for anglophone West Africa, and the *secteur sud-soudanien* of the *zone sahélo-soudanienne* plus the entire *zone sudano-guinéenne*, as defined by Boudet (1975a) for the francophone countries of the region.

Table 1 shows the extent of the subhumid zone in each of the 12 countries through which it extends. The importance of the zone from a national perspective varies widely: it accounts for 90% of the total area of Guinea and Guinea-Bissau and only 5% of Mali and Senegal, with the remaining countries falling somewhere in between. In all, it covers approximately 1.3 million km², roughly 35% of the total West African region.

The subhumid zone has been defined in various ways by a number of research workers. Though there is general agreement on the parameters which should be included in a definition, no single factor appears to be sufficient to define

Figure 1. The subhumid zone



Source: Adopted from A Blair Rains by D A W Walker.

the zone or distinguish it clearly from the semi-arid areas to the north or the humid region to the south. As the potential for livestock production in any area is determined by the available vegetation, the vegetation cover must be considered an important factor in any attempt to define a livestock zone. While the vegetation of the subhumid zone reflects climatic factors to a considerable extent, it is also modified by soils and relief and has been disturbed nearly everywhere by human activities.

The specification of exact geographic boundaries is not really necessary for a discussion of livestock development, but the factors which should be considered in characterizing the zone include:

- the climate, particularly rainfall, expressed in terms of annual precipitation and the length of the rainy season and intensity of the dry season,
- the length of the growing seasons, as determined by climate,
- the soils,
- the topography, and
- the vegetation.

For the purpose of this report, the approximate boundaries of the zone, as shown in Figure 1, have been derived in the south from the southern limit of the derived savanna vegetation zone (called the *zone pré-forestière* in the franco-phone countries), extending from the coast in the west to about 1 000 m elevation in eastern Nigeria and Cameroon. In the north, the zone is defined by the northern limit of the area with a growing season of at least 180 days.

The importance of the zone in terms of livestock production lies in its abundant grass cover (Rattray, 1969), its potential for forage and grain production, and the fact that it has so far been underexploited and carries a relatively low human and livestock population. The rainfall tends to be more reliable and the ecosystem less fragile than in the semi-arid areas to the north, where large-scale

Table 1. The subhumid zone of West Africa

Country	Total Area (km ²)	Approximate Area Subhumid Zone (km ²)	Subhumid Zone as % of Total Area
Senegal	192 000	9 600	5
Guinea	245 860	221 300	90
Guinea-Bissau	28 000	2 500	90
Sierra Leone	71 620	32 200	45
Ivory Coast	318 000	174 900	55
Mali	1 220 000	61 000	5
Upper Volta	237 800	71 300	30
Ghana	230 020	138 100	60
Togo	53 600	42 900	80
Benin	110 620	83 000	75
Nigeria	910 770	455 400	50
Cameroon	469 400	46 900	10
Total	4 087 730	1 339 100	33

Sources: Total areas from FAO (1977a). Areas in subhumid zone estimated by ILCA from Figure 1.

cattle production has traditionally been focused. If the risk of trypanosomiasis can be reduced or removed, the subhumid zone has considerable potential for a substantially improved and expanded livestock industry (Humphreys, 1977).

THE SYMPOSIUM

The International Livestock Centre for Africa (ILCA) was established in 1973 at the initiative of the Consultative Group on International Agricultural Research with a mandate:

to assist national efforts which aim to effect a change in production and marketing systems in tropical Africa so as to increase the sustained yield and output of livestock products and improve the quality of life of the people of this region.

ILCA's interest in the subhumid zone of West Africa has been stimulated by the potential of this underexploited region for expanded and improved livestock production. An expanded livestock industry in this zone would serve not only to increase the overall supply of livestock products in West African countries, but would also serve to reduce the pressure on the more densely populated and more heavily grazed semi-arid zone to the north, which has been particularly affected by the droughts of the early 1970s. At the same time, it is hoped that livestock producers who use the subhumid zone more intensively will enjoy an improved standard of living.

The National Animal Production Research Institute (NAPRI) was established in 1977 as the successor of the much older Animal Research Section of the Institute of Agricultural Research (IAR), affiliated to Ahmadu Bello University at Zaria. NAPRI has inherited the facilities of the earlier institution at Shika, near Zaria on the northern edge of the subhumid zone, and a long-standing interest in the animal production problems of the region.

ILCA established contact with NAPRI and other research institutes of Ahmadu Bello University and initiated a research programme on livestock production in the subhumid zone in 1978, centred at Kaduna, about 80 km from Zaria. It was recognized that considerable information had already been generated concerning livestock production in the subhumid zone, but this information needed to be

brought together so that remaining gaps could be identified for further research. For this reason, ILCA and NAPRI agreed to co-sponsor a Symposium on the Intensification of Livestock Production in the Sub-Humid Tropics of West Africa.

The Symposium was held in Kaduna, Nigeria from 23 to 30 March 1979, with 72 participants. Topics covered included ecology and fodder resources, livestock production and health, tsetse and trypanosomiasis, social aspects and experiences of sedentarization, and land-use administration and extension services for the pastoralists. In addition to formal discussions, field trips were conducted to the Kachia Grazing Reserve and the area around Abet where ILCA is carrying out research, as well as to NAPRI headquarters at Shika. A list of participants and events is appended to this report.

Although discussion was emphasized at the Symposium rather than the presentation of scientific papers, 16 papers were commissioned by ILCA or otherwise contributed. The present report has been prepared by ILCA staff members under the co-ordination of D A W Walker based on these background papers and the discussion which took place. Authors of individual papers are cited at the beginning of each chapter and specific references are made to published sources. An extensive bibliography on the subhumid zone is also included, broken down by subject categories, based on the reference lists provided by the authors of the background papers. The report was edited by S B Westley and typed by G Maloba.

Because the report is based mainly on material available from the Symposium, the emphasis throughout is on work in Nigeria on ruminant livestock. This emphasis is not wholly inappropriate, however, as Nigeria has the largest area in the subhumid zone of any country in the region and a great deal of livestock research and development work has been concentrated in Nigeria's subhumid zone over several decades.

2.

ENVIRONMENTAL FEATURES*

CLIMATE

The most important climatic feature in the subhumid zone is rainfall. The duration and intensity of precipitation are determined by the movement northwards, and then back southwards, of the Intertropical Convergence Zone (ITCZ) between the dry northeasterly and the wet southwesterly air streams of the region. Total rainfall generally decreases from south to north, although it is difficult to define the boundaries of the zone in terms of rainfall alone. Most definitions of the zone fall within the areas receiving 1 000 to 18 00~~0~~ mm mean annual rainfall, while, for the purpose of this report, most of the areas under consideration receive annual rainfall averaging 1 000 to 15 00~~0~~ mm. It must be emphasized, however, that these figures are only averages around which variation may be considerable. For instance, in an area with an average annual rainfall of 1 200 mm, precipitation in particular years may easily vary from 600 to 1 900 mm.

There are a number of modifications to the general rainfall pattern. Rainfall is generally greater in areas of higher elevation and also in the western part of the region, including the Casamance region of Senegal and Guinea. There is a drier zone in central Ivory Coast and southeastern Ghana and the adjacent area in

* Based on background papers presented by A Blair Rains, P N de Leeuw and J C Bille and discussion led by R Rose Innes.

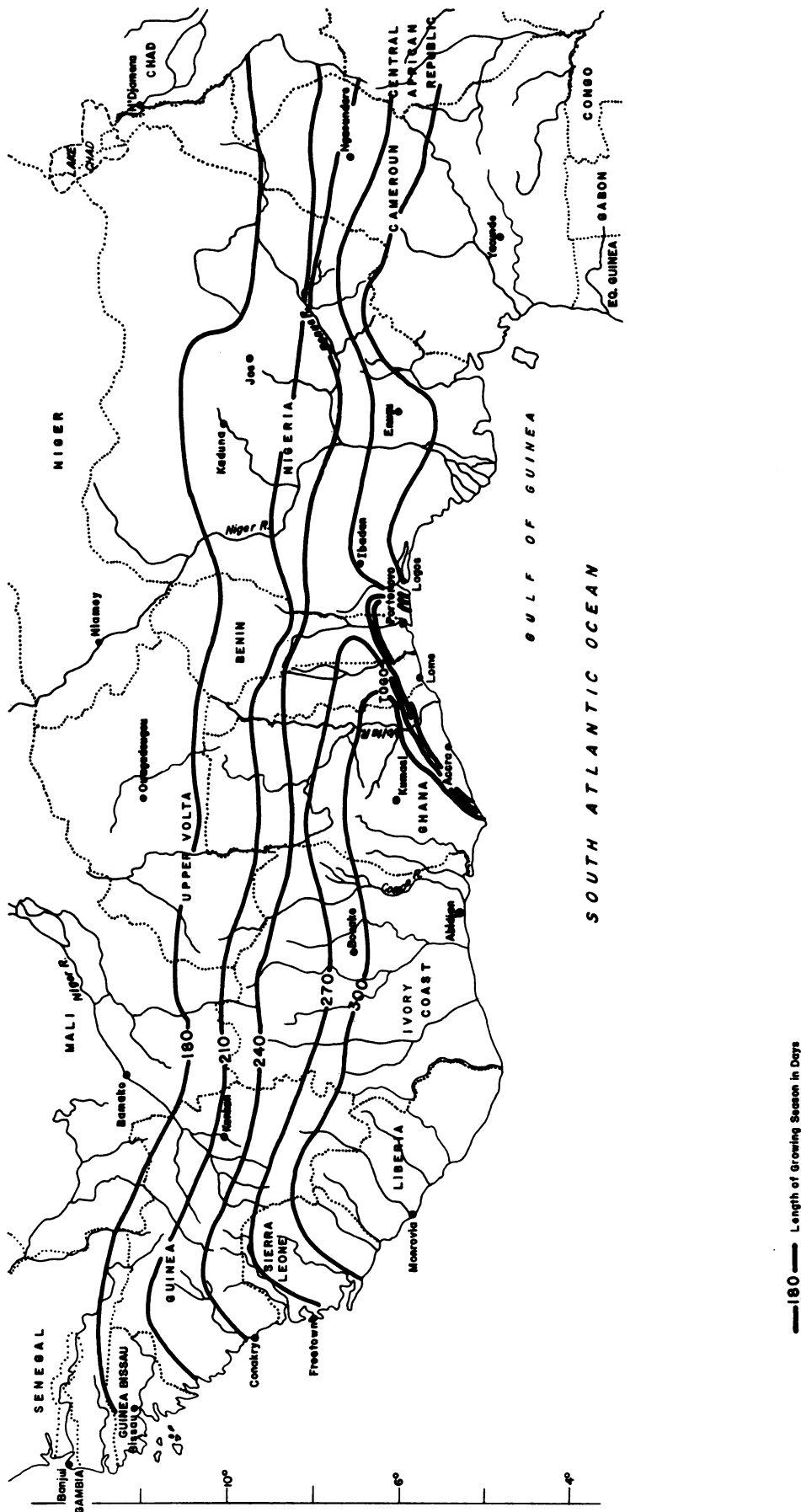
Togo. North of the eighth parallel, the rainfall distribution is usually unimodal, with the rainy season occurring from late March or early April until the middle of October. The rains in the south occur from early March to early November, but often in a bimodal pattern with a short dry period near the middle of the season.

The length and intensity of the dry season have a strong influence on the development of vegetation and the distribution of plant species, particularly in the drier northern parts of the zone. De Leeuw estimates annual potential evapotranspiration at 1 560 mm in Nigeria at the northern edge of the zone and 1 300 mm at the southern limit, with the number of months with average precipitation greater than potential evapotranspiration ranging from four to six.

The length of the growing season in the West and Central African region is depicted in Figure 2. The period of active plant growth is estimated by reference to soil moisture. It begins with the rains, as soon as there is adequate moisture in the soil, and continues beyond the rainy season as long as soil moisture is sufficient. De Leeuw calculates the growing season by adding 60 days to the length of the rainy season where soil storage capacity is high (in deep loamy soils, for instance, where storage capacity reaches 200 mm) and only 30 days where storage capacity is low (around 100 mm). As a response to rainfall, the period of plant growth becomes shorter towards the north. Different authors have defined the sub-humid zone differently in terms of the length of the growing season, but, for the purpose of this report, the growing season is considered to extend from 180 days in the north to around 270 to 280 days in the south. The climatic parameters derived by de Leeuw for the subhumid zone in Nigeria are shown in Table 2.

Climate also influences the incidence of disease among both human and livestock populations. Climatic factors, such as humidity and temperature, affect the distribution of disease vectors, most notably the different species of tsetse flies which carry human sleeping sickness and animal trypanosomiasis. High temperatures, high relative humidity and exposure to the sun also affect the behaviour of grazing animals and can adversely affect productivity, particularly when animals are maintained outside their usual environment.

Figure 2. Length of the growing season



Source: Prepared by A Blair Rains.

Table 2. Climatic parameters of the subhumid zone in Nigeria

	North (11° N)	South (7° N)
Mean annual rainfall in mm (P)	950	1 435
Potential evapotranspiration in mm (Et)	1 560	1 300
Number of months P greater than Et	4	6
Length of rainy season (days)	140	225
Length of growing season (days)	170	255
Relative humidity less than 30% at 16 00 h (months)	5-6	0-1

Source: Derived by P N de Leeuw from Kowal and Knabe (1972).

RELIEF AND SOILS

The subhumid zone consists of extensive platforms and plains generally at an altitude of 200 to 500 m above sea level. Exceptions are the troughs of the Niger and Benue Rivers, the basin of the Volta and parts of Ivory Coast, Guinea Bissau and the Casamance region of Senegal which lie below 200 m, and the Guinea-highlands, the Fouta Djallon and Jos plateaux and the upland areas of eastern Nigeria and Cameroon which lie above 500 m. Certain of the upland areas extend above 1 000 m and are sufficiently distinctive to be excluded from descriptions of the subhumid zone. They are free of tsetse and have supported substantial cattle populations since the beginning of the century or earlier.

Soil Types

D'Hoore (1964) identifies 10 main soil groups in West Africa, but only four of these are of importance in the subhumid zone, comprising together 84% of the

surface area. The iron-bearing ferruginous tropical soils which contain iron and aluminium in free form, and the lithosols, which consist of rocks, debris and ferruginous crusts, cover most of the zone, together with transitional types. The distribution of soil types is shown in Table 3.

Table 3. Distribution of soil types in the Guinea and derived savannas of West Africa

Soil Type	Deeper Soils	Shallow Soils	Total
Ferruginous tropical soils	38	23	61
- on sandy parent material	8	-	8
- on crystalline acid rocks	27	-	27
- on undifferentiated parent material	3	-	3
- weakly developed soils on ferruginous crusts and other parent material	-	23	23
Ferralitic soils	7	3	10
Lithosols	-	10	10
Transition soils	4	4	8
Hydromorphic soils	5	-	5
Eutrophic brown soils	1	2	3
Vertisols	2	1	3
Total	57	43	100

Source: Adapted from Jones and Wild (1975).

The ferruginous tropical soils occur most commonly in the savanna areas below the 1 200 mm isohyet (Jones and Wild, 1975). These soils tend to be shall - often less than 150 cm - and they are characterized by a sandy, often strongly compacted surface horizon which is low in organic matter and base exchange

capacity, which may impede drainage.

The ferralitic soils underlie most of the forest zone and the southern edge of the derived savanna. They tend to be deeper, more porous and better drained than the ferruginous tropical soils. When derived from alkaline base material, they are of medium fertility (Davies, 1973).

The transition soils combine properties of the ferruginous and the ferralitic types. They often have the favourable physical characteristics of the ferralitic soils, but are less subject to leaching and thus tend to be more fertile. Lithosols over ferruginous crusts cover large parts of Senegal, Guinea, Ghana and Nigeria (Davies, 1973; Jones and Wild, 1975). As Table 3 indicates, these and other shallow and weakly developed soils cover over 40% of the subhumid zone. Descriptions of the less important soil types in the zone may be found in Jones and Wild (1975) and Ahn (1970).

Organic Matter and Soil Nutrients

Savanna soils are characterized by low levels of organic matter. Jones and Wild (1975) analyzed the surface horizon, to a depth of 15 cm, of 245 ferruginous soils and reported an average organic matter content of 1.2%. Organic matter in forest areas tends to be considerably higher. Nye and Greenland (1960), for example, report 4 to 6% organic matter in samples of forest soils taken from Ghana and elsewhere.

Jones (1973) has hypothesized that organic matter in the soils of West Africa is positively correlated with annual rainfall, as expressed in the following formula:

$$\begin{aligned} \% \text{ carbon} &= 0.137 + 0.000865 x \\ \text{where } x &= \text{annual rainfall in mm.} \end{aligned}$$

The carbon content can be related directly to organic matter, since organic matter contains approximately 50% carbon.

Several elements play a role in plant growth and animal nutrition, but the most important is probably nitrogen. In tropical grasslands with a growing season of 150 days or longer, the main limiting factor is not moisture, but probably the availability of soil nitrogen. Nitrogen occurs in several forms, but it is only assimilated by plants as nitrates (NO_3) which are found in association with some metals. Organic matter consists of about 5% nitrogen, but the rate at which this nitrogen is converted into nitrates varies under savanna and forest conditions. This process is difficult to examine under natural conditions, but Greenland and Nye (1959) estimate an annual rate of decomposition of organic matter of 0.5 to 1.2% in grassland savanna soils and 2.5% in forest soils. Charreau and Fauck (1970) estimate an annual decomposition rate of 4.7% in dense savanna woodland. The relatively high yields of herbage obtained in the derived savanna and forest zones reflect the higher levels of organic matter in these soils and its more rapid mineralization, resulting in higher levels of available nitrogen.

In addition to decomposed organic matter, nitrogen is derived from rain water and the fixation of atmospheric nitrogen by symbiotic and free-living bacteria and blue-green algae on the soil surface and in root nodules of legumes. It is estimated that 7 kg/ha of nitrogen are obtained annually from rainfall, about one-third of which is nitrate nitrogen fixed by lightning. The amount of nitrogen contributed by bacterial and algal fixation is more variable, and pasture legumes, with their well-known ability to convert atmospheric nitrogen into nitrates of direct use by other plants, have been introduced as part of pasture improvement strategies only very locally.

Most of the nitrogen ingested by grazing cattle is returned to the soil in urine, but under systems of extensive pastoralism it is estimated that only 5 to 6 kg/ha of urinary nitrogen are returned to the soil annually. Much of this nitrogen is often lost to savanna pastures because animals are penned on arable land at night in order to increase fertility in the soil near homesteads. Total annual increments of nitrogen to the savanna soils have been estimated by Greenland and Nye (1959) to vary from 6 to 12 kg/ha, including nitrogen derived from roots, litter and animal

remains and fixed from the atmosphere. At Ejurain in Ghana, however, they estimated an annual increment of 40 kg/ha.

Mineralization and nitrification of organic matter are most rapid following the wetting of the soil after a period of drying: the more severe the drying, the greater the subsequent formation of inorganic nitrogen (Harmsen and Kolenbrander, 1965). But whereas there are marked seasonal fluctuations in the levels of ammonium nitrogen under grassland, the level of nitrate nitrogen remains low throughout the year. This has been attributed to the inhibition of nitrifying bacteria and the competition for ammonia between the bacteria and the plants. Nitrate nitrogen is almost totally absent from *Andropogon* and *Hyparrhenia* grassland, even months after land formerly under these grasses has come under cultivation.

As would be expected, the nitrogen and crude protein in the vegetation reflect the level of available soil nitrogen. Thus, most of the nitrogen in plants appears to be absorbed early in the growing season, as a result of the higher levels of nitrogen available in the soil in a wet period following a period of drying. The seasonal decline in nitrogen in herbage is especially marked in the subhumid zone since the grasses are very quick maturing.

In many soils the level of available phosphorus is also low, and this is reflected in the low levels of this element in the herbage. Moreover, in some areas the soils have been permanently damaged by uncontrolled fires and overgrazing. Where sheet erosion has occurred, the sub-surface horizon has sometimes been exposed and hardened irreversibly. In the moister parts of the zone, however, overgrazing tends to lead to bush encroachment rather than to soil denudation.

VEGETATION ZONES

The vegetation of the subhumid zone is determined by a number of environmental factors. These include climate, in particular the amount and distribution of rainfall, or inversely the intensity and duration of the dry season. Vegetation is

also influenced by the depth and texture of soils and the availability of soil nutrients, as well as human activities such as burning and cultivation. Because of the dynamic nature of the vegetation cover and its continuing disturbance by man, it is difficult to formulate a general classification of vegetation zones. French and English botanists have also used a variety of descriptive terms. Figure 3 presents two English and three French classifications, together with categories agreed upon at the Specialist Meeting on Phytogeography held in Yangambi, Zaire in 1956.

The woody vegetation ranges from semi-deciduous forest along streams in the savanna zone and in some undisturbed areas of the derived savanna to open tree savanna dominated largely by isolated trees. Tree savanna is very common in the more densely populated areas of Nigeria, Benin, Togo and Ghana. However, in most of the subhumid zone savanna woodland predominates, in particular where shallow soils and tsetse infestation have prevented arable farming. In these areas there are usually 10 to 30 larger trees per ha (trees 10 to 15 m tall and more than 30 cm in diameter at breast height), which form a discontinuous upper canopy over small tree and shrub strata which are much denser. Most species are resistant or tolerant to fire (Rose Innes, 1971). They can regenerate from seed or stumps or from underground roots and produce dense coppice regrowth after cutting (Lawton, 1975).

The distinction between the northern and southern sectors of the subhumid zone is better defined in Nigeria than in Ghana or the countries further west. The transition between the two sectors (Keay's northern and southern Guinea zone) is recognized by the relative occurrence of the woody species *Daniella oliveri*, *Prosopis africana* and *Butyrospermum paradoxum* in the south and by *Isobерlinia tomentosa*, *I. doka*, *Monotes kerstingii* and *Uapaca togoensis* in the north. Grasses are mainly tussocky perennials, especially *Andropogon tectorum*, *Beckeropsis uniseta*, *Hyparrhenia smithiana* and *Schizachyrium sanguineum* in the south. In the north perennial *Andropogon* species are common, such as *A. gayanus*, *A. ascinodis* and *A. schirensis*, as well as *Loudetia flavida*, *L. simplex* and *Elyonurus hirtiflorus*.

Figure 3. Classification of vegetation zones in West Africa

Mean Annual Rainfall mm	Trochain (1940, 1952)		Chevalier (1933)		Aubreville (1949)	Thornthwaite (1948)	Keay (1959)	Yangambi Conference (1956)	
	dornaine	secteur	région	zone					
0	saharien	saharien	sahara	midi-saharienne	saharien	arid	desert	steppe	
100				saharo-meridionale	sahélo-saharien				
200	sahélien	sahélo-saharien	soudan	sahélienne	sahélo-soudanien		semi-arid	sahel	tree or shrub steppe
300				sahélo-soudanien				sudan	
400	soudanien	soudano-sahélien		soudanaise	soudano guinéen		northern guinea	tree savanna	
500				soudano-guinéen				southern guinea	savanna woodland
600	guinéen	guinéen	forêt équatoriale	guinéene	guinéen-forestier	humid	derived savanna	dense forest	
700									
800									
900									
1000									
1100									
1200									
1300									
1400									
1500									
1600									
1700									
1800									
1900									
2000				grande forêt					

--- approximate limits of subhumid zone

Source: Compiled by D A W Walker and S B Westley.

Under severe grazing pressure, the perennial species will be replaced by annuals, including *Andropogon pseudapricus*, *A. fastigiatus* and, depending on soil conditions, *Hyperthelia dissoluta* and *Loudetia simplex*. Local variations also reflect water availability and shade.

The northern boundary of the derived savanna zone is considered by most workers to represent the limits of the original forest, reduced to savanna by shifting cultivation and fire. Remnants of the original forest are now largely confined to forest reserves, although isolated trees are also preserved on farm land. Species include *Chlorophora excelsa*, *Elaeis guineensis* and *Dialium guineense*. Smaller shrubs and trees include *Combretum grandiflorum*, *C. paniculatum* and *Allophylus africanus*, whilst common grasses are *Andropogon tectorum*, *Imperata cylindrica*, *Pennisetum purpureum* and *Loudetia arundinacea*. A number of other trees of wide ecological range are preserved by farmers because of their edible fruit. These include *Parkia clappertonia* and *Butyrospermum paradoxum*. Other species, such as *Cussonia barteri*, *Crossopteryx febrifuga* and *Bridelia ferruginea*, tend to remain because they are relatively fire tolerant.

Overgrazing has already led to ecological degradation to the north of the sub-humid zone and the relief of these areas by allowing the pastoralist herds to move further south for longer periods is one of the primary advantages of tsetse eradication and other development programmes in the subhumid zone. Purely pastoral exploitation of the savanna grasslands is unlikely to lead to the same sort of environmental problems, because in the subhumid zone overgrazing leads to bush invasion, rather than pasture denudation, and this in turn makes the area progressively less attractive to pastoralists.

Most of the subhumid zone is also considered suitable for arable farming, and as the population pressure increases and the areas of tsetse infestation are reduced it is to be expected that a substantial proportion of the land now under natural vegetation will come under cultivation. The principal agricultural crops in the northern part of the zone are cereals, particularly sorghum and millet, together with grain legumes and groundnuts. These crops are of major importance for

livestock production, as sorghum, late millet and the haulms of the legumes provide valuable fodder for stock. In the south, root crops such as yams, cassava and cocoyams are cultivated, generally on smaller farms. The root crops produce fewer residues which can be used as fodder.

In most areas, farmers are becoming more aware of the value of their crop residues for feeding their own stock or for sale to pastoralists. At the same time, the expansion of cultivation often obstructs the movement of stock to grazing land or water. Damage to growing crops and, in some countries, the unauthorized use of residues frequently result in disputes and litigation. The cultivation of flood plains further reduces valuable grazing land, and the more valuable of the natural grasses are slow to reestablish after cultivation. As cultivation expands in the subhumid zone, strategies must be devised for protecting the soils and the more useful natural plant species and for achieving the closer integration of arable cropping and livestock production.

3. THE LIVESTOCK PRODUCERS

POPULATION

It is difficult to obtain precise population figures for the subhumid zone, though in general the region is sparsely populated. The coastal area to the south has one of the highest population densities on the African continent. In the coastal regions of Sierra Leone, Ivory Coast, Benin and Nigeria population densities are in excess of 300 per km². Relatively high population densities are also found in the dry Sudanian zone to the north, reaching 250 to 350 per km² in north-central Nigeria and north-eastern Ghana.

The subhumid zone, on average, probably has a population density of less than 20 per km². This relatively low population is partially attributable to environmental conditions such as seasonal climatic extremes, vigorous woody vegetation and the relative poverty of the soils. The incidence of sleeping sickness has also undoubtedly played a role, as well as the history of slaving. According to Morgan and Pugh (1969):

to the north-west of Nupe country are almost empty areas of savanna woodland, depopulated by the slave raids of the Sarkin Sudan (the Emir of Kontangora) at the end of the 19th century. Although rainfall in this area is relatively low (about 1 015 mm per annum), reliability is above average; and there seems to be no reason why a normal population density should not be supported.

* Based on papers presented at the Symposium by M Awogbade and J E Ekpere and discussion led by C E Hopen and further notes by G Philippon.

The current annual rate of population increase is estimated at over 2% for West Africa as a whole, and it is inevitable that immigration into the subhumid zone from the more densely populated areas will be substantial. In some areas this trend is already apparent, for instance in Nigeria. Rates of immigration are difficult to predict, but it seems likely that all the land in the subhumid zone of Nigeria suitable for cultivation will be occupied in 30 years, and that a similar situation will occur within 40 years in Sierra Leone, Ghana and Togo.

AGRICULTURAL GROUPS

The agricultural people of the zone tend to belong to small, fragmented ethnic groups. They are distinct from the large clusters of state-building peoples to the north and south, except for the people of the Malinke heartland around Kankan and Siguiri in Guinea. In the western part of the zone, about a dozen groups speak West Atlantic languages, including Fulani. In the centre of the zone, there are numerous small groups, mostly speaking languages of the Gur family. The groups of the Nigerian subhumid zone mostly speak Benue-Congo (i.e. Bantoid) or Chadic languages, with a few Kwa-speaking groups who have probably come into the region from the south (e.g. Nupe-Gwari).

Many of these groups display archaic forms of social organization and cultural life which have led some authors to classify them as 'paleonigrific' (Baumann and Westermann, 1967; Frolich, 1969). The ethnic pattern of the zone suggests a history of weaker groups pushed back into this region from the south and the north. In this respect, the 19th century slave raids may just have been one last stage of a longer-term pattern, in which the subhumid zone, handicapped by its remoteness from both the trans-Saharan and the Atlantic trade routes, has served as a refuge for relatively weak population groups.

THE FULANI PASTORALISTS

The agricultural people of the subhumid zone sometimes keep a few domestic animals, but any discussion of livestock production must focus on the Fulani pastoralists whose flocks and herds account for nearly all the livestock kept in the region.

Fulani-speaking groups are found throughout the subhumid zone, though their total numbers are not known. They originated in Senegal, and are thought to have reached the Hausa areas of Nigeria during the 15th century. Traditionally, they bring their animals only into the subhumid zone during the dry season, when they come from the north to take advantage of the considerable grazing resources available.

Although they share a common language, the Fulani vary widely in their social organization and modes of production. There are pastoralist Fulani groups in the western parts of their range, but these are less well known than the powerful settled groups, such as the Fouta Djallon Fula of Guinea and the Tukolor of Senegal, who keep livestock but also practise agriculture. Most of the published information on pastoralist Fulani comes from the areas further east, including Niger, Nigeria and Cameroon. This discussion will concentrate on these pastoralist groups, particularly those found in Nigeria. Their livestock production systems are described in the later chapter on livestock resources and management systems.

Fulani Social Organization

The primary social unit among the pastoralist Fulani is the household camp. Fulani households are not fixed entities, but are subject to fission and recombination in response to social factors and seasonal shifts in ecological conditions. Such a household camp normally consists of a core of related males with their wives and children, but it is not always based on kinship. These household groups also do not stand in precisely defined relation to others in terms of lineages or clans. Affiliation to the larger lineage and clan groups is recognized only in rather general terms.

The composition and size of the Fulani pastoralist camps vary. For example, Dupire (1970) determined from a sample of about 300 camps (*qure*) of Wo'daa'be Fulani in Niger that 46 to 60% consisted of single polygynous families (one man with his wives and children), 20 to 25% consisted of groups of married brothers with their families, 13.5 to 21% consisted of fathers with one or more married sons and their families, and 3.5 to 7% consisted of other combinations of male kinsmen.

The household camps combine during the dry season to form transhumant lineage groups. The size of these groups varies from year to year, or even within one season, but some observers believe they are generally associated with a given territory which remains stable, though it may be shared with other groups. Stability is also encouraged by a strong preference for endogamous marriages: in some instances up to 80% of all marriages take place among members of the transhumant lineage group. Out of a sample of 371 marriages recorded by Dupire, 57 men married the daughter of their father's brother, 27 married the daughter of their father's agnatic cousin, 19 married the daughter of their father's sister, and 28 married the daughter of their mother's brother.

Two larger groupings are also recognized, both called *lenyol* (pl. *lenyi*) in Fulani, but distinguished according to how they were formed. The first grouping, called primary lineage by Dupire, consists of a former transhumant lineage group which no longer moves together. Individuals may be affiliated with such groups through agnatic kinship, cross-cousin relationships or collective oaths. The second larger grouping, called maximal lineage by Dupire and clan by Stenning (1959), probably corresponds to a political unit of the pre-colonial era (see Stenning, 1959), but has lost all significance beyond a vague awareness of common origin. These groupings have no specific territorial basis.

The Subsistence Economy of the Fulani Household

A domestic group among the Fulani begins with a marriage within the agnatic

kinship group, usually based on infant betrothal in the case of a man's first marriage. A domestic unit can only become independent, however, when it has enough members to carry out the basic economic activities necessary for subsistence. The concept is expressed by Stenning (1959) as follows: 'Such a domestic unit is viable when the labour it can provide is suitable for the exploitation of its means of subsistence, while the cattle are adequate for the support of the members of the domestic unit'.

Within the household group, a number of cattle are distributed to the various 'huts' (ful. *suudu*, pl. *cuu'di*), each occupied by a wife and her children. Each wife receives cattle from her husband at the time of her marriage, and she may also have received a few animals from her father. The milk produced by this herd belongs exclusively to the woman and her children, whether used for consumption or for sale, and the children inherit these animals from their mother. However, while the family is together the father usually manages these animals as well as his own herd. The milk from his cattle is generally needed to help meet the consumption needs of his wives and children. He distributes his animals to his sons as they grow older and marry.

Young boys and adolescents are responsible for herding and men are responsible for milking among the settled groups and women among the transhumants. Married women sell milk and purchase grain, and both men and women do minor craft work at a relatively undeveloped level. The general management of the herd is the exclusive responsibility of the household head, particularly in regard to decisions on where and when to move.

The management of the herd requires almost constant attendance at markets and other gathering places where information is obtained on such vital factors as pasture conditions, rainfall and the incidence of disease. Because of this, the household head who must herd his own cattle is at a serious disadvantage in making management decisions. For this reason, a man will not leave his father's household until he has a son eight or nine years old who can look after his cattle, even though he may have a viable herd of his own. He may act as his father's assistant in planning the management of the herds, while his own cattle are tended with those of

his father by a young unmarried brother.

As a man's sons grow older, they gradually produce their own sons and leave him. By the time his last son marries and raises a son of herding age, all the father's cattle will have been distributed and his domestic group will cease to exist. In fact, the father often dies before all his sons have established their own households. When this happens, his remaining herd is shared among his heirs according to complex rules (Dupire, 1970).

It is very difficult to obtain reliable figures on the size of Fulani herds. Such information is concealed for cultural and economic reasons, most importantly to evade cattle tax. It is sometimes argued that, for cultural reasons, the Fulani keep more cattle than their economic needs would require, but more precise calculations suggest that Fulani herds are barely large enough to meet the pastoralists' minimum subsistence requirements. Van Raay (1975) estimates that the nomadic Fulani keep an average of 10 cattle per person, which corresponds closely with Stenning's calculations of an average of 50 cattle for a household of 5.1 members. According to Dupire, the average number of cattle per person varies from 4.5 to 5.0, though these figures are likely to be underestimated because they are based on notoriously unreliable cattle tax returns. Among the semi-nomadic Gwandu Fulbe, Hopen (1958) found an average household size of 5.57 persons keeping 30 cattle, or roughly 5.3 cattle per person.

The basic sources of subsistence among the Fulani are milk and grain, though meat is also consumed on special occasions. The most important cereal is bulrush millet (*Pennisetum typhoides*). De St. Croix (1945) describes the Fulani diet as follows:

An undoubted preference is shown by the Fulani for preparations made from bulrush millet, with other grains used only when this one is scarce Meat is seldom eaten except on festive occasions ... nor are quantities of meat considered to be of great value in the diet: the 'Fulani's meat' consists of milk and butter.

On the other hand, Van Raay (1975) considers meat a fairly important component of the diet:

It is true that the killing and slaughter of animals predominantly occurs in a ritual and ceremonial context ... but it should be remembered that crowds of fellow Fulani are always invited to such occasions and take advantage of the unusual opportunity to supplement their monotonous diet with meat. Given the fact that many occasions will be held annually in the direct surroundings, such opportunities will offer themselves quite frequently.

The supply of milk comes from the family herd, meat is shared among a larger group of pastoralists, and grain is obtained by cultivation or by purchase from farmers. Thus, although Fulani households produce primarily for subsistence, they must almost always exchange products with others to overcome deficiencies in their own internal resources, at least at certain times of the year. Two production models can be hypothesized: one which includes the cultivation of grain crops at some time during the year and one which does not. However, as Hopen (1958) asserts in reference to the Gwandu Fulbe Fulani, 'only a small percentage indeed ... have never farmed within their memory'.

Van Raay's (1975) surveys in the Katsina and Zaria areas of Nigeria reveal the following typical herd structures:

	Adult Females	Adult Males	Bulls 1-3 yrs	Heifers 1-3 years	Calves
Katshina	43.9%	10.5%	13.4%	15.3%	17.9%
Zaria	40.5%	8.4%	13.4%	17.5%	20.2%

Assuming that just under half the adult cows in a herd are in milk at any one time, then 18 to 20% of the total number of animals would be cows in milk.

Assuming an average daily yield per cow of about 1.0 litre during the rains and 0.5 litre during the dry season, Stenning's household herd of 50 would produce about 9.5 to 10.0 litres of milk for human consumption during the rains, dropping to around 5 litres at the peak of the dry season. Hopen's herd of 30 would include about six cows in milk at any one time, producing not more than 6.5 litres per day during the rains and as little as 3.0 litres at the driest time of year.

Dahl and Hjort (1976) calculate that a pastoralist family of six consuming only milk would need about 16.6 litres daily, so that a family of 5.1 would need 14.1 litres. It is clear that a typical Fulani family cannot live on milk alone, even during the wet season. A family of average size would require 70 cattle to subsist on milk during the rains, though only about one-fourth of the Wo'daa'ba households surveyed by Stenning kept herds of this size. To subsist on milk alone during the dry season, a family would require more than 140 cattle, though none of the households in Stenning's sample had such large herds. The households in Hopen's sample could expect to obtain only one-half to one-fifth of their daily nutritional requirements from milk.

Awogbade (1977) carried out a linear regression analysis to determine the number of cattle necessary for a pastoralist family to subsist wholly on milk under conditions prevailing on the Jos Plateau in Nigeria. His results are indicated by the expression

$$y = 30.5 + 9.3 x$$

where y is the expected herd size for a household of x members. This suggests that a household consisting of a man and one wife would require about 50 cattle, with an additional 9.3 head needed for each additional household member, coming to about 78 cattle for a household of five people. Of the 31 households surveyed in connection with this study, none had any surplus cattle beyond those required for their subsistence needs.

The shortfall in milk consumption must be compensated by the consumption of meat and grain. Dahl and Hjort (1976) estimated that an annual offtake of about 8% is possible without reducing a 'basic herd' which is growing at a normal rate. This is approximately the proportion of a normal herd composed of old cows and old bulls which are no longer productive plus young bullocks in excess of the number required for reproduction. In other words, about four cattle could be slaughtered or sold every year out of a herd of 50. Small stock are slaughtered more regularly, but there is no reliable information on actual offtake rates.

Given a livestock production system primarily oriented towards milk production, it can be assumed that most of the animals sold or slaughtered would be excess steers or cull cows. However, in recent years several observers have noted an unusually high proportion of females in Nigerian markets, including those of breeding age. The cattle observed in Kano abattoir in January 1976 were 80% female, and averages of over 50% are common. At Maradi, Agades and Diffa in Niger, over 60% females were reported slaughtered in 1974, and this situation still continues in markets further south. There is not enough information available to determine why this situation has occurred or what it implied for the status of pastoralist production systems.

The quantities of grain purchased or cultivated and consumed are also difficult to calculate. Incomes were quoted during the Symposium of about US \$ 557 in 1974 from the sale of milk, rising to about US \$ 1 120 by 1979. These incomes compare favourably with general rural income levels and would permit the pastoralists to purchase sufficient quantities of grain and other items to meet their subsistence needs, providing these commodities are available. One advantage of a transhumant system which brings pastoralists and their livestock into agricultural areas during the dry season is that milk can be sold and grain purchased at the time of year when grain is most needed to supplement the diet of the pastoralists.

Sedentarization Among the Fulani

Most development plans for the subhumid zone call for at least partial settlement of the traditional livestock producers. For this reason, the process of spontaneous settlement which has already occurred among some Fulani groups is of considerable interest.

It is difficult to estimate the proportion of Fulani who have become settled, particularly as census figures are unreliable. In Nigeria, Van Raay (1975) estimates that 12% of the Fulani are fully nomadic, 38% are semi-settled and 50% are settled, though the settled pastoralists own proportionately fewer cattle, accounting

for only about 40% of the total herd.

There seems to be no doubt that settled Fulani tend to keep smaller herds than the transhumant pastoralists, and that they rely more heavily on agriculture to meet their subsistence needs. Modern industrial consumer goods are also more in evidence among settled communities, such as watches, radios, enamel and plastic ware, bicycles and motorcycles.

Very little information is available, however, on the factors which lead to sedentarization. A number of possibilities have been hypothesized, including:

- political or religious events,
- loss of cattle due to epidemics or drought,
- reduction of grazing land due to the expansion of the agricultural population,
- desire for consumer goods (perhaps most important among the younger generation).

Only the first case has been relatively well documented. Stenning mentions that some leaders of migratory household camps were made village heads by the local government administration in Nigeria. These individuals settled and became *haa'be*, which means that they lost many of their cattle, either through redistribution to their followers or simply because it was not possible to maintain substantial herds without practising transhumance. The village areas over which they were appointed were initially set out by the administration in line with traditional wet-season grazing areas, but, in fact, the needs of the transhumant Fulani, whose movements shift according to rainfall and other environmental conditions, could not be accommodated in these fixed areas. According to Stenning (1959) 'the more southerly a village area, the less will be its utility in a year of good rainfall' and vice versa. Thus, the appointed village heads and their households inevitably adopted a sedentary lifestyle and became assimilated with the local Hausa or Kanuri agricultural populations.

One of the duties of the village heads was to collect the cattle tax, out of which a certain proportion was returned to the local government. These leaders tended to make agreements to collect the taxes of specific transhumant groups, perhaps from the same lineage, although the pastoralists were not necessarily in a particular village chief's area at the time of tax collection. Apparently it has been advantageous for transhumant Fulani groups to have a kinsman as a village head, as shown by the fact that the lineages with such a connection have not moved permanently out of Borno State in Nigeria since 1918, while other lineages are now found in the area only occasionally in scattered groups.

There is little information on the incidence of settlement due to loss of cattle. Some authors have suggested that once settled pastoralists have expanded their herds they tend to revert back to a transhumant lifestyle, but no cases of this reversion have been documented. If loss of cattle is an important factor influencing settlement, this would suggest that the settled pastoralists have been the least successful in terms of animal husbandry.

There is also very little information on the size of settled pastoralist groups. It is not known whether individual households decide to settle independently or whether the decision is taken by the larger transhumant lineage group, though most authors consider that settlement occurs by individual household units.

4. FODDER RESOURCES AND MANAGEMENT *

HERBACEOUS VEGETATION

According to Rattray (1969), the grass cover of the subhumid zone can be classified into two broad belts: the northern part of the zone where *Andropogon gayanus* predominates and the southern area where the *Hyparrhenia* species are more important. More recent rangeland surveys, however, have shown that although climatic variation brings about a modest segregation of grass species, soil conditions, in particular soil depth and texture, and site history, especially related to cultivation and burning, have a much greater impact on the species composition of savanna vegetation than climate (Boudet, 1975a; de Leeuw, 1978a). The principal grass species of the subhumid zone are shown in Table 4 in relation to soil types and woody vegetation.

Biomass Production

The upper and lower limits of end-of-season herbage yields at a number of sites in the subhumid zone are shown in Table 4. Yields range widely from 1 500

* Based on papers presented by A Blair Rains, P N de Leeuw, J C Bille and W Doppler and discussion led by R Rose Innes.

to 18 000 kg DM/ha. In contrast to the modest effect of latitude on the distribution of grass species, the quantity of herbage growth increases markedly from north to south on rangelands with similar species composition. For instance, annual yields at Olokomeji, near Ibadan in southern Nigeria, were found to be twice as high as at Shika further north (see Table 5). It has been suggested that the main factor determining yield is the longer growing season in the south, rather than the higher mean annual rainfall (de Leeuw, 1978a).

In addition to the effects of latitude, grass yields are closely related to the catenary sequence of soils. The lowest yields are recorded on stony, shallow and gravelly soils which have a low, sparse grass cover, partly consisting of annual species. Highest yields are associated with deep loamy soils, usually ferrisols, in the derived savannas where tall grasses thrive (Lamotte, 1975; Boudet, 1975a; Egunjobi, 1973). On shallow soils over ferruginous crust at Shika, yields rarely reach 2 500 kg DM/ha, compared to a production of 6 000 kg on deep, sandy alluvial clays in the same area (see Table 5). Similar differences in yields according to soil types have been recorded by Afolayan (1975) in the Borgu Game Reserve in Nigeria and by Lamotte (1975) in Ivory Coast.

Shade from the woody canopy not only affects species composition of the grasses (see Table 4), but also affects herbage yields. At Afaka, near Kaduna in Nigeria ($10^{\circ} 35' \text{N}$), the annual herbage yield in places without tree cover was found to average 3 200 kg DM/ha, compared with 2 300 kg DM/ha in more shady places at the same location. However, the shade tolerance of the tall woodland grasses, called 'fringe grasses' by Rose Innes (1977), is high; they are only suppressed in areas where the tree canopy is almost entirely closed. This explains why in *Isobерlinia tomentosa* woodland in northern Nigeria with a tree cover of 66%, a dense tall perennial grass cover (53%) survived, yielding 3 500 kg DM/ha annually, when subjected to late annual burning (Afolayan, 1975).

In shrub savanna, woody cover is usually inversely related to grass yield, since low shrubs compete directly with grasses for light, and probably for moisture and soil nutrients as well. Rose Innes and Mansfield (1976), working on the Kaduna

Table 4. Principal grass species of the subhumid zone in relation to soil types and woody vegetation plus limits of annual herbage yield

Soils	Iron crust and rock outcrops			Shallow soils		Deep soils		Deep soils (clayey)		Deep Soils (Sandy)	Variable soils
Woody vegetation	Shrub savanna and savanna woodland			Savanna woodland		Woodland (with heavy shade)		Tree savanna & savanna woodland		Savanna woodland	Old fallows
Location (north or south)	N	S	N	N	S	S	S	N&S	S	S	N&S
Perennial grasses 0.6 - 1.2 m tall											
<i>Andropogon ascinodis</i>	XXX	XX	XXX	XXX				X		X	
<i>A. schirensis</i>	X	X	XX	XX		XX		X		X	
<i>Brachiaria jubata</i>								XX			
<i>Ctenium newtonii</i>	XX	XX	X	X						X	
<i>Elyonurus pobeguinii</i>	X		X								
<i>Hyperthelia diosoluta</i>								XX		X	
<i>Loudetia simplex</i>	XXX	XX	XX	XX				XX			
<i>Monocymbium cersiiiforme</i>			XX	XX				XX			
<i>Schizachyrium sanguineum</i>	X	XX	XX	XXX		X		X		XX	
<i>Setaria anceps</i>								XXX			
<i>Sporobolus pyramidalis</i>								X			
<i>Trachypogon spicatus</i>	XX	X	X								
Perennial grasses 1.2 - 2.5 m tall											
<i>Anropogon gayanus</i> var. <i>bisquamulatus</i>			X	X				X		XXX	XX
<i>A. gayanus</i> var. <i>squamulatus</i>											
<i>A. tectorum</i>								XXX			
<i>Beckeropsia unisetata</i>								XX			X
<i>Elinandra androphila</i>		XX		X							
<i>Hyparrhenia diplandra</i>				XXX		X		XX		X	
<i>H. rufa</i>											
<i>H. smithiana</i>		X	X	XX		X				X	
<i>H. subplumosa</i>			X	XX		X				X	
<i>Imperata cylindrica</i>											
<i>Loudetia arundinacea</i>		XX		X							XX
<i>Urelytrum muricatum</i>	X	X	X	X		X					
Annual grasses											
<i>Anropogon fastigiatus</i>	X		X							X	XX
<i>A. pseudapricus</i>	X	X	X								XX
<i>Aristida</i> spp.	X										
<i>Hyparrhenia involuvarata</i>										XX	X
<i>Loudetia hordeiformis</i>										XX	
<i>Pennisetum</i> spp.										X	XX
Annual yields (t DM/ha)											
- low	1.5	2.5	3.0	4.0	4.0	4.0	5.0	3.0	3.0	5.0	4.0
- high	3.0	6.0	6.0	8.0	6.0	6.0	18.0	6.0	6.0	18.0	6.0

XXX = abundant or very common; XX = common; X = occasional; X = occasional
Sources: Adapted from Schmidt (1973), Boudet (1975a), Boudet and Ellenberger (1971), Cesar (1975) and de Leeuw (1978); nomenclature according to Clayton (1966).

plains in Nigeria, estimated the standing biomass on four- to eight-year-old wooded fallows at 1 000 to 1 200 kg DM/ha, or less than half the average measured on older tree savannas or undisturbed savanna woodland.

Despite these large differences in end-of-season yields, most perennial grasses in a monsoonal climate follow a similar pattern of growth. After a short initial period of slow growth in the early rainy season, vegetation growth is linear for three to four months until stem elongation occurs preparatory to flowering, when growth again accelerates. This period of rapid growth begins in late August for short grasses in the northern part of the zone, but occurs several weeks later in the south. Tall grasses generally mature later than shorter species.

As the end of the growing season approaches, growth rates decline, as shown in Table 5. At Shika in Nigeria, on shallow gravelly soils under shrub savanna, the growth rate of the grasses begins to drop in mid-October, whereas at sites further south or with deeper soils, the growth rate begins to drop more than one month later. The sites under comparison included a savanna woodland area at Ol'okomeji, a tall grass savanna on deep colluvial soils along the Shika River and a tall *Andropogon gayanus* grass savanna on deep sandy soil at Fashola, all in Nigeria. These differences in rangeland production are reflected in daily vegetative growth rates which can vary from 15 to 57 kg DM/ha, increasing to a range of 29 to 145 kg DM/ha towards the end of the rains. Egunjobi (1973) recorded a peak daily production of 270 kg DM/ha on *Andropogon gayanus* fallow at Fashola, which is in contrast to only 32 kg DM/ha for the same species at Shika (Haggar, 1970).

In the drier areas of the subhumid zone, growth rates diminish rapidly as soon as the residual moisture supply in the soil is exhausted. In southern Mali, which is relatively dry, low daily growth rates of 0.8 to 2.5 kg DM/ha were measured early in the dry season (Boudet and Ellenberger, 1971), while at Shika, which is also a relatively dry area, very little growth was observed after cutting in October (Haggar, 1970). In more humid regions, the growing season is more prolonged. Piot and Rippstein (1975) recorded a daily growth rate of 2.7 to 4.5 kg DM/ha on the Adamawa Plateau in Cameroon at the end of a 240-day growing season,

Table 5. Herbage accumulation in ungrazed rangeland at four sites in Nigeria (tonnes DM/ha)

	May 1	June 1	July 1	Aug 1	Sept 1	Oct 1	Nov 1	Dec 1
Shika (11° N)	0.10	0.35	0.75	1.45	2.40	3.20	3.10	3.00
Shika River (11° N)	0.35	0.65	1.20	2.70	4.10	4.10	6.15	-
Olokomeji (7° 25' N)	1.30	2.00	3.00	3.70	4.80	5.65	6.00	6.10
Fashola (7° 55' N)	1.70	3.20	5.20	5.50	11.60	16.20	15.30	-

Sources: For Shika and Shika River, de Leeuw (1971a) (data collected in 1968); for Olokomeji, Hopkins, private communication (data collected in 1957-58); for Fashola, Egunjobi (1973).

while in the even more humid forest savanna mosaic, Boudet (1975a) recorded daily growth rates early in the dry season of 5 kg/ha for *Loudetia arundinacea* on shallow soils and 7 to 8 kg/ha for *Hyparrhenia diplandra* on deeper soils.

As the dry season continues, growth is further reduced until the soil moisture deficit is replenished by the early rains and growth recommences. Growth rates at the beginning of the rains are also greatly affected by the climate and the depth of the soil as shown in Table 6.

Table 6. Daily growth rates of burned vegetation during the second half of the dry season and the early rainy season at five sites in the subhumid zone

	Daily Regrowth (kg DM/ha)	
	Late Dry Season	Early Rainy Season
Savanna on shallow soils at Yanfolila, Mali (11° N)	1.5	-
Shrub savanna on shallow soils at Shika, Nigeria (11° N)	1.9	8.8
Grass savanna on deep, low-lying soils at Shika, Nigeria (11° N)	6.1	13.6
Savanna woodland at Olokomeji, Nigeria (7° 25' N)	-	22.9
<i>Andropogon gayanus</i> grass savanna at Fashola, Nigeria (7° 55' N)	-	41.3

Sources: For Yanfolila, Boudet and Ellenberger (1971); for Shika, de Leeuw (private communication), burning between late December and mid-April, figures derived from regression equation, $y = 1.93x + 14.4$ ($n = 28$, $r = 0.81$), where x = days after burning and y = DM yield in kg/ha; for Olokomeji, Hopkins (private communication); for Fashola, Egunjobi (1973), burning in late February.

Nutritive Value

Several elements may be considered in evaluating the nutritive value of savanna forage, such as the nitrogen, calcium, phosphorus and potassium content. However, crude protein (CP) content, measured as a percentage of dry matter, is closely related to the other parameters of nutritive value, and may be used as a sensitive indicator of overall herbage quality. The crude protein content of forage has also been shown to have an overriding influence on animal performance (Zemmelink, 1974).

The feeding value of forage, as measured in terms of crude protein content, varies with the season and the physiological status of the plant, to a degree that differs among the different grass species. Most perennials, for example, are

capable of some regrowth almost throughout the year, but the decline in crude protein content with time and plant maturity is very rapid: in fact, crude protein content is rarely over 6% of total herbage for more than three months out of the year.

The fall in crude protein content with the age of the plant seems most pronounced for tall grasses, where the decline is about 1% for every 10 days of plant growth (Boudet, 1975b). For some species, crude protein content also depends on the season during which the plant grows: a plant is physiologically younger, and thus of higher nutritive value, if it grows during the dry season than a plant of the same age growing during the rains. During the rainy season, as long as residual soil moisture is available, crude protein content declines at the same rate as the decline in growth.

For many species, defoliation by grazing, cutting or burning stimulates regrowth of higher nutritive quality than that of continuous growth during the same period. For other species with strictly fixed life cycles, such as *Hyparrhenia diplandra*, aging continues regardless of defoliation and the feeding value is inadequate from August until the following rains.

For various rangelands around Shika, forage growth of 60 to 90 days was found to contain between 4 to 6% CP (Haggar, 1970; de Leeuw, private communication). During the late dry season, fairly high crude protein content has been recorded after burning or grazing. At Yanfolila in Mali, Boudet and Ellenberger (1971) found $7.2 \pm 0.4\%$ CP after 20 to 30 days' regrowth on upland savanna and $9.5 \pm 1.6\%$ CP on lowland savanna. After 55 to 65 days' regrowth on upland savanna at Shika, de Leeuw (private communication) found $5.3 \pm 0.2\%$ CP, while Boudet (1975a) found $15.7 \pm 1.4\%$ CP for *Echinochloa/Oryza* spp. on flood plains. Table 7 shows the percentages of crude protein found at different times of the year for upland shrub savanna under three different treatments.

Data on the crude protein content of total herbage may be unreliable in that they do not take into account the variation in crude protein between different parts

of the plants. The figures in Table 8 show that the crude protein content of *Andropogon gayanus* is much higher in the top growth than in the rest of the plant. If this pattern also applies to other tall grass species, selectively grazing animals will obtain a diet of higher nutritive value during most of the rains and into the early part of the dry season than would be assumed from an assessment of the crude protein content of total herbage alone. As the dry season progresses, however, the crude protein content diminishes throughout the plant. Out of 273 grass samples analysed at Shika, 85% contained less than 4% CP, and 25% contained less than 2.5% CP (Brinckman and de Leeuw, 1975).

Table 7. Crude protein content under three different rangeland treatments at Shika, Nigeria (% DM)

	1 May	1 June	1 July	1 Aug	1 Sept	1 Oct	1 Nov
Ungrazed, burned							
Upland	8.1	8.1	6.7	4.7	3.9	3.5	2.5
Old fallow ^a	9.3	9.4	6.5	4.2	4.2	4.2	3.0
Fadama grassland	9.9	10.4	6.5	4.1	3.7	3.0	2.6
Grazed, burned ^b							
Green herbage	-	9.7	8.5	7.2	6.0	4.9	3.7
Total herbage	-	8.8	7.5	6.1	4.8	3.5	2.1
Grazed, not burned ^b							
Green herbage	-	7.7	7.1	6.4	5.7	5.0	4.3
Total herbage	-	3.7	3.6	3.5	3.4	3.2	3.1

a. Old fallow on deep colluvial soils with *Setaria anceps*, *Hyparrhelia dissoluta*, *Andropogon gayanus* and *Sporobolus pyramidalis* as dominant species.

b. Lenient wet-season grazing; green herbage refers to the upper 30 cm of the sward.

Source: de Leeuw (1971a).

Table 8. Crude protein content (CP) and in vitro digestibility (dig.) for different plant components taken from *Andropogon gayanus* pasture towards the end of the growing season

	12 September		3 October		26 October	
	CP (%DM)	dig. (%DM)	CP (%DM)	dig. (%DM)	CP (%DM)	dig. (%DM)
Young leaves	6.8	66.0	8.7	56.6	6.6	54.4
Old leaves	2.1	49.5	3.1	29.2	3.4	39.4
Young stems	3.1	64.1	5.4	56.8	4.6	42.6
Old stems	1.2	53.6	1.5	44.9	1.1	32.5
Whole plant	4.1	-	3.7	-	3.0	-

Sources: For leaf and stem data, Hagggar (1970); for whole plants, Hagggar and Ahmed (1971).

WOODY VEGETATION

The importance of woody vegetation for livestock production in the subhumid zone lies in its competition with grasses and its contribution of browse to animal nutrition, which can be particularly important at times when grazing is in short supply. In the more humid areas, most management systems follow a strategy of reducing the growth of trees by burning. Mechanical measures, such as felling or ringing, and chemical treatment have also been practised occasionally. In general, it seems most economic to clear young plants before reforestation becomes advanced.

Browse is not considered as important a component of animal diets in the subhumid zone as in the Sudanian and Sahelian zones farther north because the number of woody species acceptable to stock is limited and grass is generally available. At Shika in Nigeria, only 11 of 42 shrub species identified were readily consumed, while 17 species, which accounted for over 50% of the shrub canopy, were avoided altogether (de Leeuw, 1979). Boudet (1975a) and Boudet and

Ellenberger (1971) reported similar findings from other sites in the subhumid zone. They recorded only 10 shrub species which are acceptable to livestock.

The usefulness of browse lies mainly in the high feeding value it provides at seasons when other roughage sources are of low quality. From 41 samples of subhumid species, for example, two-thirds were found to have a crude protein content of over 10%. In general, browse contains more calcium, phosphorus, magnesium, and potassium than grasses (Brinckman and de Leeuw, 1975). Piot (1970) discusses the value of a number of common subhumid species, including *Daniella oliveri*, *Gardenia ternifolia*, *Hymenocardia acida*, *Lophira lanceolata*, *Piliostigma thonningi* and *Vitex madiensis*. Leaves of these species were found to contain 8 to 17% CP and 0.2% P. Other species utilized as browse are *Khaya senegalensis*, *Azelia africana*, *Pterocarpus erinaceus* and the fruits of *Parkia clappertonii* and *Prosopis africana*.

Actual data on the browsing behaviour of stock are scarce. Van Raay and de Leeuw (1974) found that late in the dry season (March to early July) 15 to 20% of the feeding time of semi-nomadic herds in the Sudanian zone was spent browsing, while sedentary herds in the subhumid zone spent only 3 to 6% of their feeding time on browse. Paddocked cattle at Shika browsed for 12 to 15% of their total feeding time in March and June, compared with only 4% in February when many shrubs are leafless or have only mature leaves. The pronounced seasonality of browsing behaviour is associated with the new flush of foliage which appears on the browse plants with the onset of the hot and humid weather preceeding the rains, a period when grass tends to be in short supply. In many parts of the northern subhumid zone, herdsmen climb large trees and lop off the branches for their animals to supplement the low-growing shrubs, coppicing shoots and fallen leaves and fruit that are readily accessible.

High acceptability and intake rates have been recorded for woody species in the Miombo woodlands of Zambia (Rees, 1974) and for thicket species on the Accra plains in Ghana (Rose Innes and Mabey, 1964). Considering the scarcity of data,

further assessment is needed of the browse value of the woody species of the sub-humid zone.

PASTURE MANAGEMENT

Grazing

The effects of grazing on pasture growth and species composition depend on the frequency and timing of defoliation, the selectivity of the grazing animals, and soil and climatic conditions. In general, certain species, such as *Andropogon tectorum*, tend to disappear under even relatively light grazing, to be replaced by species such as *Brachiaria brizantha* or *Setaria sphacelata*, without decreasing overall pasture productivity. As grazing increases, most of the palatable grasses are replaced by short-cycle annuals, such as *Sporobolus* and *Eragrostis* spp., or by species which the animals reject, such as those of the *Malvaceae* and *Solanaceae* families. Extreme overgrazing is followed by denudation and soil erosion in the drier northern parts of the zone, or by bush encroachment in the south, forming dry *Arthrosamanea* forests, secondary forests or composite forests with *Harungana*.

Under traditional management, pastures in the subhumid zone are grazed primarily during the dry season. There is little information on changes in species composition or herbage yield following prolonged wet-season grazing. However, work at Shika suggests that cattle grazing rangeland with a variety of grass species tend to be rather unselective, avoiding few species completely (de Leeuw, 1979). Grazing behaviour appears to be governed by the age of the herbage, rather than by preference for particular species, leading eventually to a mosaic pattern of closely grazed and ungrazed patches (Cesar, 1975).

It is likely that changes in the species composition of pastures under heavy grazing are due to differences in the ability of particular species to withstand repeated defoliation, rather than to selective grazing behaviour per se. Grazing

tends to favour the shorter grasses, such as *Setaria*, *Bracharia* and *Paspalum*, and those which mature early, such as *Sporobolus pyramidalis* and *Hyperthelia dissoluta*, rather than the tall and late-maturing *Hyparrhenia* spp. However, the resistance to grazing of the tall perennials varies considerably, depending on the timing and frequency of defoliation and the soil type. Plot and Rippstein (1975) observed that populations of *H. rufa* and *H. filipendula* decreased on shallow soils under grazing, but increased on deep colluvial soils. A similar pattern was observed by Cesar (1975) in Ivory Coast, while in Kafanchan and on the Jos plateau in Nigeria, *Hyparrhenia* species have been found to withstand prolonged heavy grazing and on protection to revert to tall stands similar in composition to ungrazed savanna.

Intensive grazing may lower overall pasture yields due to succession from tall to shorter grasses and also result in lower net annual herbage production among those grass species which remain. At Shika, it was found that growth 60 to 90 days after defoliation averaged 27% less than uninterrupted growth. On the Adamawa Plateau of Cameroon, frequent defoliation (every 20 to 30 days) resulted in cumulative yields which were 25% lower than yields with less frequent cutting every 60 to 80 days.

However, the rapid seasonal decline in the nutritive value of the herbage can be minimized by defoliation. Several trials have shown that yields of digestible nutrients, including protein, from grazed areas are higher than from cut areas; similarly the yield of crude protein from an area which had been grazed during the first part of the season was shown to be nearly as high as that of an ungrazed adjacent area. These results must be attributed to the smaller proportion of mature herbage on grazed areas and to the return of dung and urine. On a lightly stocked paddock the plant nutrients obtained from urine and dung are unlikely to increase herbage production, but on a heavily stocked paddock the return of nutrients (80% of the ingested nitrogen) is likely to be significant. The distribution of dung and urine on a paddock will always be uneven, however, and much will be lost by oxidation.

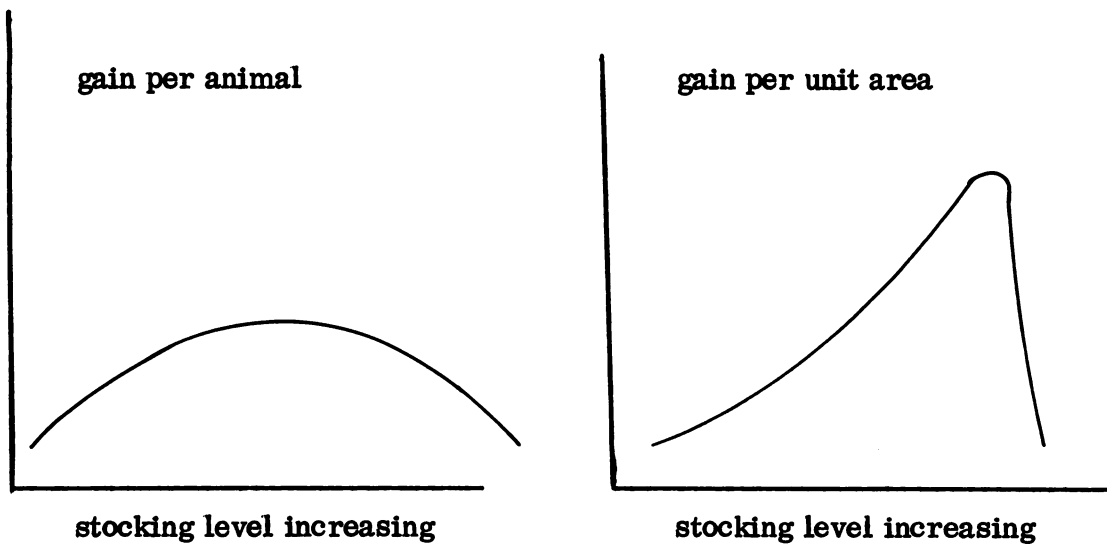
When animals are confined in paddocks, they tend to graze a limited area closely to which they frequently return. In this way, they provide themselves with a supply of comparatively nutritious herbage throughout the growing season. The grazed 'lawn' can be composed of the original natural species which adopt a prostrate habit or of sub-climax species. In the ungrazed areas, a certain amount of the more palatable leafy material from the tussocks will be consumed. In appearance there can be very distinct grazed and ungrazed areas, or there can be frequent tussocks growing in a matrix of grazed grass. The proportion of grazed to ungrazed grasses is probably determined by the level of stocking.

The major constraint on most wet-season grazing systems is the lack of herbage of suitable quality during the dry season. Although repeated defoliation maintains the level of nutrients, there is only a limited amount of palatable material on offer at the beginning of the dry season. During this season, animals therefore need access to a larger area where they can graze selectively. This area could be lightly stocked with mature animals during the growing season, who would also have access to the tightly grazed lawns. For increased dry-season fodder production, sod seeding with legumes has also given promising results in a number of situations.

The detailed system of grazing (whether continuous, rotational or deferred) has to be adapted to the type of grassland and to its condition. However, a number of trials have indicated little difference in animal performance or in the botanical composition of pastures between different systems of grazing management, except for degraded areas or those under extremely high stocking levels. The stocking level affects liveweight gain per animal, liveweight gain per unit area and the pattern of selective grazing.

With many types of grassland, an increase in the number of livestock per unit area produces changes in gain per animal and in gain per unit area which are well known. However, comparison of the results obtained from wet-season grazing trials undertaken on medium to tall savanna grasses, particularly *Andropogon*, *Hyparrhenia* and similar genera, suggests that the regression between stocking level and gain per animal is not linear and that the highest gains are not obtained at

the lightest stocking level. The regression for stocking level and gain per unit area is also different in the case of these grasslands. In Nigeria (Shika) unimproved shrub savanna stocked at a rate of one tropical livestock unit (250 kg liveweight) to 1.6 to 2.0 ha during the growing season gave better liveweight gains than either lighter or heavier stocking (de Leeuw, 1971a).



Because of the importance of protein for animal production, the supply of this nutrient could be used as a basis for estimating carrying capacity. A 250 kg animal requires 200 g digestible crude protein per day (160 g for maintenance, plus 18 g per 100 g liveweight gain) or 75 kg digestible crude protein per year. In fodders containing 7% crude protein, this level of digestible protein is approximately equivalent to 140 kg crude protein per year. The sustained yield of protein varies according to site and soil type from 60 kg to 200 kg per ha annually throughout the subhumid zone: if by frequent grazing the protein content is maintained at a satisfactory level and the total yield of protein is not affected by the frequent defoliation, then an area which provides 140 kg of crude protein will support an animal of 250 kg liveweight. If, in order to control shrub regrowth, a burn every third or fourth year is considered necessary, there will be a reduction in the carrying capacity by a third or a quarter, i.e., from 1:2 ha to 1:2.6 ha. Carrying capacity will also be lower on *Isoberlinia* or *Daniella* woodlands than on open savanna. Where the tree canopy is 60% or greater, the carrying capacity will be nearly 1:6 ha.

A rotational grazing system was successfully implemented on relatively moist savanna at Ubangi, Zaire over a period of ten years with very little decrease in productivity or disturbance to the species composition of the grassland (IEMVT, 1974). The dominant grass species in this area is *Hyparrhenia diplandra*, which can produce 12 000 to 16 000 kg DM/ha annually when undisturbed. A five-paddock rotational grazing system was initiated with a very low stocking rate, designed to result in annual consumption of only 3 000 kg/ha, or 20 to 25% of total potential herbage production. Each paddock was burned once a year and grazed for a period of three months, beginning 100 days after burning. Analysis indicated a favourable crude protein content of about 10% of dry matter for the pastures under grazing.

The dry-season use of subhumid pastures by livestock that move north during the rains can be regarded as a rotational grazing system on a large scale. The shrewd use of a variety of fodder resources by transhumant producers is evidenced by the generally more prosperous appearance of their animals compared with sedentary herds in the same areas, though their freedom of movement is becoming increasingly limited by the spread of townships, roads and cultivated fields.

Evidence points to great resilience of pastures in the subhumid zone under transhumant dry-season and light wet-season grazing, but the rangeland does deteriorate seriously under prolonged heavy grazing and it is important to avoid stocking levels which are too close to the 'peril point' where the grasslands deteriorate rapidly. At Shika, for example, overgrazing has created large areas of stable 'terminal' grassland, consisting of low-yielding prostrate species such as *Brachiaria stigmatistata*, *Tephrosia pedicellatum*, *Sporobolus pyramidalis* and annual weeds. In parts of Ivory Coast, Cesar (1975) found that annual sedges and grasses replaced virtually all perennials under similar heavy grazing conditions.

Fire

During the dry season, savanna rangelands have traditionally been burned to

clear tall grass and stimulate the replacement of old and unpalatable material with fresh herbage. This use of fire has long been a controversial issue. Van Raay (1974) condemns it out of hand, while others have considered it a useful management tool available to traditional farmers and pastoralists. In Nigeria, sedentary pastoralists often blame the use of fire on the transhumants, or *bororo*, but in fact they themselves make extensive use of the regrowth after fires to supplement the low protein levels available from the desiccated grazing late in the dry season. ILCA herd behaviour studies at Kachia near Kaduna indicate that animals spend over four hours a day grazing fire regrowth during the latter part of the dry season after crop residues have declined in importance.

The response of the savanna ecosystem to frequency and time of burning has received considerable attention, but most published studies have focussed on changes in the tree cover rather than on effects on grasses. This emphasis is due to the general opinion that frequent fires are essential to prevent bush encroachment and have little or no effect on the fire-tolerant grasses which dominate most savannas (Ramsay and Rose Innes, 1963; West, 1965). Afolayan (1977) has reported that under northern subhumid savanna conditions, late burning for two consecutive years can reduce the regeneration of tree seedlings by up to 80%, while in areas which are burnt early in the season or not burnt at all the number of seedlings increases.

It has generally been found that changes in grass species composition under burning are slow, and short-term effects are difficult to detect (de Leeuw, 1978a; Ramsay and Rose Innes, 1963). However, early burnt areas may tend to become dominated by annual grasses and forbs while late burnt areas tend to become dominated by perennials (Afolayan, 1977). West (1965) found that burning increased grass production in moist savanna areas, but reduced yields in more arid regions. This conclusion is supported by data from five locations in Nigeria presented in Table 9.

The effects of burning warrant further study in different parts of the subhumid zone. With increased cropping and sedentarization of livestock production, grazing pressure is likely to become greater and the role of fire and the results of burning will acquire an increased significance. Changes in crude protein content and dry

Table 9. The effect of early and late burning on herbage yield at five locations in Nigeria (tonnes DM/ha/year)

	Early Burning	Late Burning	Protected Not Burned
<i>Isoberlinia</i> shrub savanna at Shika ^a	2.20	2.23	2.18
<i>Detarium</i> savanna woodland at Borgu ^b	2.09	3.62	1.56
<i>Isoberlinia</i> woodland at Borgu ^c	1.93	3.51	1.83
<i>Terminalia macroptera</i> tree savanna at Borgu ^d	4.11	6.89	3.78
<i>Andropogon gayanus</i> grass savanna ^e at Fashola	17.83	16.37	15.27

- a. Yield after six years of burning (1968–74) on upland site; early burning in late November or December, late burning in March or early April.
- b. Sites located in Borgu Game Reserve (10° N); mean yields over two years (1974–75) with years of burning unknown; early burning in late November or December, late burning in March or early April. This site on shallow soil over ironstone; dominant grass species are *Loudetia flavida*, *Hyparrhenia involucrata* and *Andropogon pseudapricus*.
- c. As above, but with 66% canopy cover on deep colluvial soil; shade-tolerant grass species dominate.
- d. As above, but on deep valley soils, seasonally flooded; dominant grasses tall *Hyparrhenias*, including *H. rufa* and *H. smithiana*.
- e. Deep sandy soil with tall grasses dominant; burned one year (1969/70) on 22 December and 27 February; latitude 7° 55' N.

Sources: For Shika, de Leeuw (personal communication); for Borgu, Afolayan (1975 and private communication); for Fashola, Egunjobi (1973).

matter yield should be investigated, as well as the impact on subsequent yields of early grazing of the regrowth.

Cutting

The effects on pasture lands of grazing and successive cutting are similar but not identical. Cutting retards the development of inflorescent stems and may extend the period of growth by 30 to 45 days, but productivity declines, stabilizing at a lower level during the third year of any particular cutting strategy. In some cases, the species composition may also be slightly modified. The reduction in yields over a period of three years at Bouar in Central African Empire under a system of cutting three times a year is shown in Table 10.

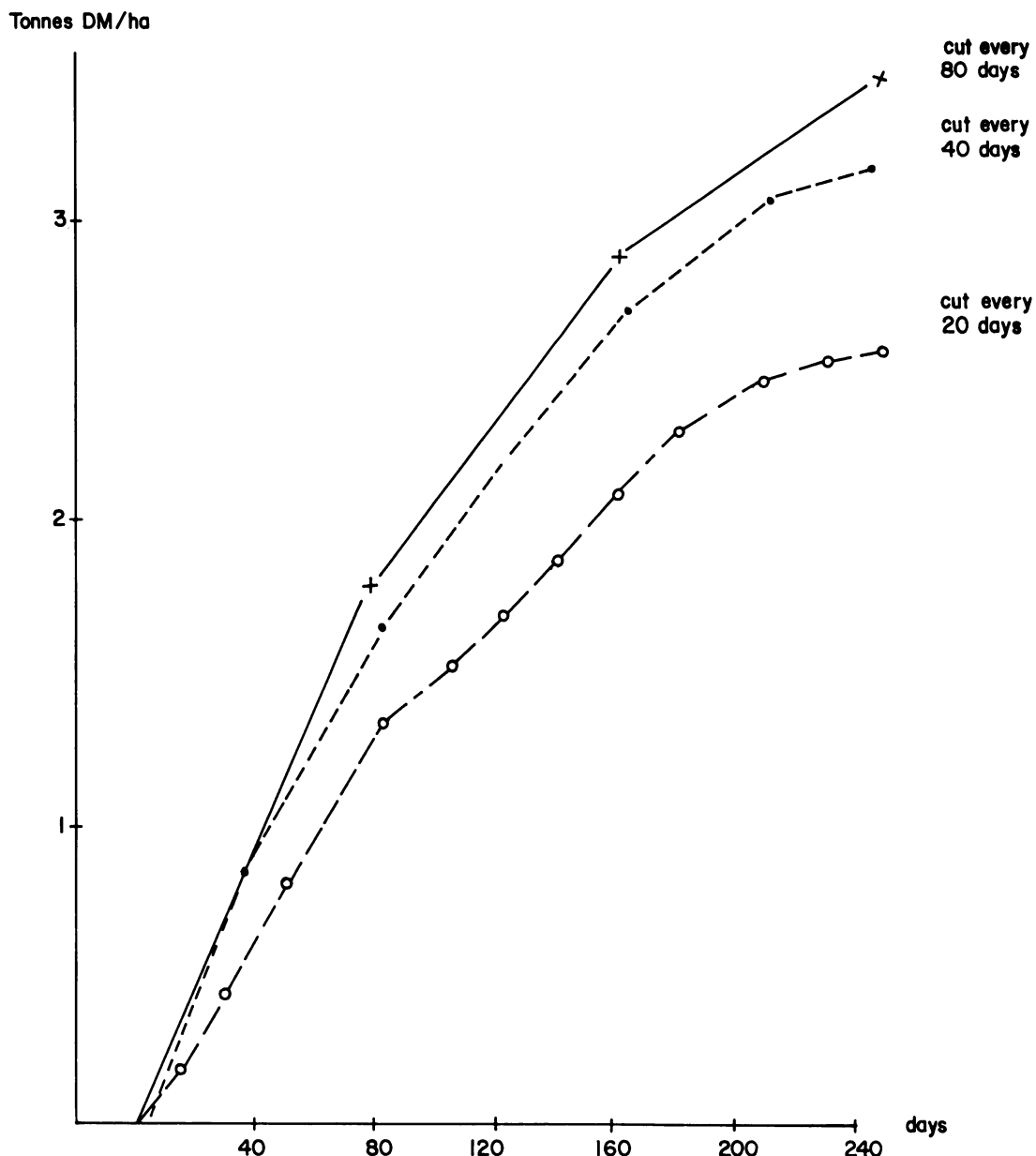
Table 10. Green matter yields at five sites at Bouar (CAE) when cut three times a year (tonnes/ha/year)

	Year 1	Year 2	Year 3
Forest savanna	11.0	8.5	7.7
Savanna on concretions	6.3	5.0	5.0
Savanna on colluvial soil	16.1	14.9	13.0
Savanna on ferralitc soil	19.5	14.5	11.8
Overgrazed savanna	14.6	12.0	11.7

Source: Bille and Hédin (1968).

Productivity may decline at a faster rate if the utilization rate is increased. In another experiment carried out at Bouar (Bille and Hédin, 1968), dry matter yields were 3 400 kg/ha on pasture cut three times during the growing season, diminishing to 3 200 kg/ha when cut six times, 2 800 kg/ha when cut eight times and 2 500 kg/ha when cut 12 times, as shown in Figure 4. The time of defoliation also affects growth rates: Haggar (1970), working at Shika, found that *Andropogon gayanus* regrew at a daily rate of 11 kg/ha when cut at the vegetative stage before August 12, but regrew at a rate of only 5 kg/ha when cut later in the season.

Figure 4. Pasture productivity at Bouar (CAE) when cut 3, 6 and 12 times (tonnes DM/ha)



Source: Bille and Hédin (1968).

Sown Pasture

The advantages of pastures sown with high-yielding forage grasses and legumes lie mainly in the higher levels of forage production achieved, both in terms of quantity and quality. Leguminous species are particularly attractive because of their ability to convert and utilize atmospheric nitrogen. However, the high costs of pasture sowing and the level of management required in order to sustain produc-

tivity limit the adoption of this management strategy to certain specific situations. Comprehensive reviews of pasture sowing, covering species selection and adaptation, as well as the effects of fertilizer application and management on quality and yield, are found in Blair Rains (1963), Ruthenberg (1974), Dumas and Coulomb (1978) and de Leeuw and Agishi (1978).

Research in several countries has served to identify promising pasture grass and legume species and appropriate methods of sowing and maintaining improved pastures. *Stylosanthes humilis* has been identified as a very attractive legume for this purpose and has been sown successfully in Australia from aeroplanes without cultivation on burned pastures at the beginning of the growing season. Broadcasting without cultivation failed when it was tried at Shika in Nigeria because the soil formed a crust which the seeds or seedlings could not penetrate. Techniques of sowing without cultivation might be more successful on sandy soils, but competition from the perennial grasses must also be reduced and a fairly large population of legume seedlings must be established at the outset. Experience from elsewhere in West and Central Africa has shown that *Stylosanthes* seed can be established successfully by broadcasting from the ground when competition from existing grasses is reduced by prior burning or heavy grazing. Once a pasture is established with 20 to 30% *Stylosanthes*, the grazing animals can maintain it, at least for a few years on fairly open land, by ingesting and excreting the seed if they are allowed to graze when the seed is mature but still in the heads. No cultivation is required.

Though it has been shown possible to establish *Stylosanthes*, all large-scale trials in West Africa have failed eventually because the *Stylosanthes* has disappeared after a few years. On very fertile land, this has been due to competition from the grasses, while on overgrazed or eroded land the soil becomes compacted and cannot be penetrated by the *Stylosanthes* seeds. The plants are also destroyed by fire. In addition, *Stylosanthes* tends to become stemmy after two or three years and is subject to termite attack. Faster-maturing varieties are needed, which will produce seed before the pastures are burned at the end of the growing season,

though usually such varieties also produce less green foliage during the dry season. The varieties which have shown promise so far include *Stylosanthes humilis*, an annual and *S. guyanensis*, a perennial. Cultivars of other species which require further evaluation in the area include *S. hamata*, *Macroptilium atropurpureum* and *Centrosema pubescens*.

The costs and returns of livestock production systems based primarily on sown pastures have been estimated by Ruthenberg (1974) and de Leeuw and Agishi (1978). Unfortunately, these estimates are difficult to interpret or compare because of rapid inflationary trends in both input costs and beef prices. Ruthenberg concludes that breeding ranches grazing N'Dama cattle on pastures sown with *Stylosanthes* are on the whole not viable economically, but fattening and growing-out operations may break even if the livestock weight produced annually reaches 200 kg/ha. De Leeuw and Agishi compared beef production based on pastures sown to pure grasses and to grass-legume mixtures, as well as production based on unimproved rangelands. Supplementation with high-protein concentrates during periods of pasture deficiency was also considered, resulting in a comparison between six production systems, as shown in Table 11. The difference between gross income and costs for the six production systems ranges from US \$ 22 to 198 per ha. The most attractive strategy in economic terms appears to be grazing on natural savanna with supplementation. The second most attractive strategy is year-round grazing on improved legume-based pasture.

An economic analysis was carried out recently of beef production and pasture improvement programmes initiated in the subhumid zone at Avetonou, Togo, comparing extensive and intensive ranching conditions (Doppler, 1979). Pasture improvement strategies considered include pastures planted with *Panicum maximum* - *Centrosema pubescens*, *Stylosanthes guyanensis* - *Cynodon dactylon* and natural pasture improved with *C. dactylon*. The primary objective of this analysis was to consider the economic incentives for pasture improvement from the viewpoint of a small-scale farmer and a livestock producer on a somewhat larger scale.

These combinations of grass and legume species were chosen to maximize

fodder availability during the dry season. The natural pasture improved with *Cynodon dactylon* gave a relatively constant yield during the dry season, while the *Stylosanthes guyanensis* - *C. dactylon* combination provided good standing hay. The application of fertilizer in September at the end of the rains was also analysed. This approach appeared to be more expensive than the provision of alternative feeds during the dry season, such as grass silage, maize silage or concentrates. However, the use of fertilizer is nevertheless desirable because it tends to curb the growth of unpalatable weeds and shrubs.

All the systems of improved pasture management devised were found to be uneconomic in terms of beef production. An increase of cattle prices of approximately 50% would be necessary to obtain a positive rate of return. Alternatively, methods of establishing and maintaining improved pastures would have to be developed at substantially reduced costs.

In addition to poor profitability, the pasture improvement systems devised at Avetonou would require substantial financing to meet their high investment costs. Under the extensive ranching system tested, an area of 28 000 ha would be stocked with 6 012 cows and 301 bulls, at a value of about US \$ 1.1 million. Such a capital-intensive operation with low profitability would involve an unacceptably high level of risk, even if credit for the initial investment were available. It would also be very difficult to procure the required number of animals. Based on this analysis, it was concluded that, given present production techniques and cost-price relationships, no viable large-scale beef ranches could be expected to emerge from the private sector and any large-scale government ranches would have to rely on considerable injections of outside funds.

Livestock production based on sown pastures might be economically justified on well-managed grazing reserves if used to replace savanna grazing for selected classes of stock, such as pregnant and lactating cows or young calves, to provide night grazing in order to extend the daily grazing period, or to provide a reserve of fodder for emergencies such as uncontrolled fires or drought. Used in this way, improved pastures might help relieve one of the major constraints on livestock

Table 11. Input-output analysis of six livestock production systems in Nigeria

a. Wet Season - six months						
	Grass Pastures (no supplement)		Legume Pastures (no supplement)		Natural Savanna (supplement) (no supplement)	
Stocking rate (kg lwt/ha)	800		300		150 150	
Daily gain (kg)	0.50		0.50		0.60 0.25	
Yield for season (kg lwt/ha)	288		108		65 27	
b. Dry season - six months						
	Legume Pastures supple- no sup- ment plement		Legume Pastures supple- no sup- ment plement		Natural Savanna supple- no sup- ment plement	
Stocking rate (kg lwt/ha)	600	600	300	300	50	150
Daily gain (kg)	0.50	0.25	0.50	0.25	0.25	- 0.04
Yield for season (kg lwt/ha)	216	108	108	54	35	- 7.00
Annual yield (kg lwt/ha)	252 ^a	198 ^a	216 ^b	162 ^b	100 ^b	20 ^b
Total Income (US\$)	408.20	316.80	345.60	259.20	160.00	32.00
Management costs (US\$/year)	152.00	152.00	112.00	112.00	9.60	9.60
Cost of supple- ments (US\$/year)	68.80	-	35.20	-	28.80	-
Total costs	220.80	152.00	147.20	112.00	38.40	9.60
Margin ^c (US \$/ha)	182.40	164.80	198.40	147.20	121.60	22.40
Input/output ratio	0.56	0.53	0.43	0.43	0.24	0.33

a. Stock grazed on grass pastures for six months and on legume pastures for six months, with both pastures left ungrazed for half the year; therefore the annual production is the mean of the two grazing periods.

b. Legume pastures and savanna assumed to be grazed year round; thus annual production is the sum of the two grazing periods.

c. Monetary output calculated on the assumption that 1 kg liveweight = 1 Naira, and 1 Naira = US \$ 1.60.

Source: de Leeuw and Agishi (1978)

production under traditional pastoralist systems, which is the short grazing day combined with the long distances covered during the daily orbit (van Raay and de Leeuw, 1974). It is important, however, that sown pastures on a grazing reserve be kept under the strict control of family or cooperative units who are also responsible for maintenance costs.

Pasture sowing might also be an appropriate strategy for arable farms in the subhumid zone. In areas where pressure on the land is still low, fallow periods are relatively long - they may last from five to seven years. Natural fallows could be oversown with forage species, in particular with *Stylosanthes*, or the last crop in the rotation could be undersown (Thomas, 1975; de Leeuw, personal communication). These fallow pastures would need to be properly managed under the control of individual farmers; they could be used in the same ways as sown pastures in grazing reserves.

Improved pastures could also be an important component of livestock production on breeding and fattening ranches. Experience with ranch development in the subhumid zone, on Mokwa Ranch in Nigeria (Hübl et al., 1974), suggests the advantages of a balanced combination of arable farming, including such crops as sorghum, maize and soya beans, followed by several years of grass-legume pastures (*Panicum*, *Centrosema*, *Stylosanthes guyanensis*) on the better soils and the less productive land left to natural savanna. This would provide an income from the sale of crops to offset clearing and cultivation costs as well as a diversity of roughages, including crop residues, to make possible a wide range of management and feeding strategies.

Fodder Crops

Several experimental fodder production projects have been carried out in the subhumid zone. High yields have often been reported, but it has not always been clear whether these yields were sustained over several years or how much fertilizer was required. Fodder trials carried out at Bobo Dioulasso in Upper

Volta (Sikora et al., 1976), including annual and perennial grass species and legumes, gave daily productivity levels ranging from 160 to 190 kg DM/ha for the annuals, with a growing period of about 100 days, and from 180 to 210 kg DM/ha for the perennials, with a growing period of about 240 days. The legumes produced about 100 kg DM/ha daily. Results by plant species are presented in Table 12.

Table 12. Fodder productivity at Bobo Dioulasso, Upper Volta

Species	Growing Period (days)	Annual DM Yield (kg/ha)	Daily DM Yield (kg/ha)
<i>Brachiaria ruziziensis</i>	243	49 811.00	204.98
<i>Panicum maximum</i>	212	38 359.00	180.94
<i>Stylosanthes gracilis</i>	245	23 010.00	134.73
<i>Centrosema pubescens</i>	244	16 982.00	69.60
<i>Glycine wightii (javanica)</i>	245	15 844.00	64.83
<i>Sorghum rio</i>	125	19 704.00	157.63
<i>Canavalia eusiformis</i>	122	22 948.00	188.09
<i>Stylosanthes humilis</i>	117	8 089.00	69.13
<i>Cajanus cajan</i>	71	7 031.00	99.03

Source: Sikora et al. (1976).

A fodder trial carried out over a three-year period at Bouaké in Ivory Coast (Roberge et al., 1976) suggests that yields generally drop over the years: without fertilizer, productivity during the third year was only 47% of the level reached in the first year. Even with substantial fertilizer applications (up to 712 N, 675 K₂O and 216 P₂O₅ annually), productivity had decreased by 25% by the third year. However, annual production of *Panicum maximum* was maintained at 40 000 kg DM/ha under irrigation (though the level of water intake was not specified) and with fertilizer applications at the rate of at least 550 N, 200 P₂O₅, 810 K₂O, 220 CaO and 290 MgO.

Use of Crop Residues

Crop residues are an important component of the forage supply of traditionally managed herds, particularly along the northern fringes of the subhumid zone and in the drier areas to the north. Residues comprise only a minor proportion of the total forage supply throughout the year because their availability is highly seasonal, but in the early part of the dry season after the harvests, from December to February, they have been shown to account for 75% of the total roughage supply of transhumant animals and 50% of the total supply available to sedentary herds. The contribution of crop residues from various sources has been estimated by van Raay and de Leeuw (1974) under transhumant and sedentary pastoral systems, as shown in Table 13.

Table 13. Sources of annual roughage intake as % of total daily grazing time under two pastoral management systems in northern Nigeria

	Transhumant Pastoralists	Sedentary Pastoralists
Savanna Grazing		
Upland savanna and fallows	59	60
Lowland grass savanna (valleys)	13	22
Browse	9	4
Total	81	86
Crop Residues		
Sorghum	12	10
Millet	1	-
Groundnuts	3	2
Cowpeas	-	2
Cotton	3	-
Total	19	14

Source: Derived from van Raay and de Leeuw (1974).

In the Kano Close Settled Zone, an intensive agricultural area in northern Nigeria, crop residues account for over 80% of the total year-round forage supply. The period during which these residues are available is extended in this area mainly through fodder conservation and storage (Hendy, 1977). The annual production of crop residues has been estimated by several authors (Rose Innes and Mansfield, 1976; van Raay and de Leeuw, 1970), but general estimates of yield levels based on particular situations are of limited value due to the wide variety of crop mixtures planted, levels of fertilizers and other inputs used. However, the estimates provided by Hendy (1977) for the intensive farming system in the Kano Close Settled Zone suggest yield levels which are likely to obtain in other similar areas of the subhumid zone. These estimates are presented in Table 14.

Table 14. Average roughage resources on farms in the Kano Close Settled Zone of northern Nigeria

	% of Cultivated Land under each crop	DM Yield (t/ha)	CP Content (% DM)		% of Total Digestible CP Produced
			During Growing Season ^a	After Harvest	
Sorghum leaves	40	1.6	6.0	3.0	14
Millet leaves	27	1.0	6.0	3.0	3
Groundnut haulms	16	1.5	12.7	7.7	46
Cowpea haulms	13	1.6	17.5	12.5	36
Other crops	4	1.5		4.0	1

- a. The high CP content of sorghum and millet refers to leaves stripped during the growing season; for legumes, the CP content is based on early harvested and well cured hay.

Source: Derived from Hendy (1977).

Hendy estimates annual production of all residues at 1 400 kg DM/ha, of which 40% is legume hay, mostly of good quality. Because 75% of the land in this area is under crops, producing substantial quantities of roughage, a high stocking level of two tropical livestock units (equivalent to 250 kg each) can be maintained per ha, composed mainly of sheep, goats and donkeys.

Throughout most of the subhumid zone, the traditional utilization of crop residues has been limited to the grazing of sorghum stover by transhumant herds and local sheep and goats. Moreover, there is a gradual shift from north to south in the zone, from cereal to root crop farming with a resulting decrease in available residues. Sorghum retains an important role in areas where a yam-sorghum cropping pattern predominates, but is replaced by maize in areas where yam-cassava production is more important. Forage-producing legumes are also much less important towards the south.

The utilization of crop residues implies a mixed production system combining arable farming and livestock. Yet development planning in some countries of the region, notably in Nigeria, is focusing, at least in part, on large-scale mechanized cereal production with the role of crop residues for livestock feeding likely to be minimal. In this context, research is needed on the relative profitability of mono-cropping in various areas compared with the possibilities for mixed production systems including a livestock component.

5. LIVESTOCK RESOURCES AND MANAGEMENT *

The livestock resources of the subhumid zone include cattle, sheep, goats, pigs and poultry, though this report focuses on the ruminant species. Population estimates are often unavailable or unreliable, but in general the livestock population of the zone is much below the potential carrying capacity. The cattle population fluctuates widely throughout the year, as transhumant herds are brought down from the north during the dry season and taken back at the onset of the rains. In Nigeria, for example, transhumant cattle account for about 6 million head out of an estimated national herd of 8 to 11 million.

LIVESTOCK TYPES

Cattle

The most important factor determining the presence of cattle in the subhumid zone is the incidence of tsetse-transmitted trypanosomiasis. The Zebu breeds (*Bos indicus*), which are susceptible to trypanosomiasis, have traditionally been found in the northern part of the zone under transhumant conditions, while the trypanotolerant breeds (*Bos taurus*) have been kept in small sedentary herds in the

* Based on papers presented by W Ferguson, A A Ademosun, R von Kaufmann, C Hoste and A Blair Rains and discussion led by D H Hill.

south. Exotic *Bos taurus* breeds from the temperate regions, which are highly susceptible to trypanosomiasis, have been imported in small numbers on an experimental basis. In some cases they have been crossed with local types, for example at the government stock farm at Shika in Nigeria, where Friesians have been crossed with White Fulani Zebu, and at the Centre de Recherche Zootechnique de Minankro-Bouaké in Ivory Coast, where N'Dama x Jersey crosses have been studied. These exotic breeds and their crosses are unlikely to feature prominently in development programmes in the subhumid zone for some time, until production and management systems have been improved substantially.

There also seems only limited scope at present for moving indigenous breeds into parts of the subhumid zone where they have not been kept traditionally. Zebu breeds, with their higher milk potential, have been kept in the southern part of the zone under prophylactic treatment for trypanosomiasis, though the management and veterinary requirements are very high. The trypanotolerant breeds, on the other hand, often appear better adapted to the moister, shadier parts of the zone and when kept in drier areas lose condition and are more susceptible to disease. They also tend to be less attractive to the pastoralists of the northern areas.

Mason (1951) identified 12 breeds of Zebu cattle in West Africa, classified as short- and long-horned types. In a survey carried out in northern Nigeria, Lamorde and Franti identified 51% of the cattle as Bunaji (White Fulani) with medium to long horns, followed by 14% Rahaji (Red Bororo) with long lyre-shaped horns. They found 11.5% medium-horned Adamawa Gudali, 11.5% short-horned Sokoto Gudali and the remaining 12% divided between several other breeds. In other parts of the zone, different breeds assume greater importance.

In the past, it was widely believed that the local Zebu breeds were poor producers, but it has been shown that these cattle, under proper feeding and management, can achieve favourable production levels. The white Fulani has been widely recognized in Nigeria as a good dual-purpose animal. Oyenuga (1967) stresses these qualities by quoting a study carried out by Hartley and Baker (1935) reporting milk

yields of 1 082 kg over 305 days, with 7.5% butterfat. Hill (1956) reports milk yields of 2 475 kg over the same period from White Fulani cows at the University of Ibadan farm. Shaw and Colville (1950) observe that:

This breed has given exceptionally good results, responding well to improved feeding and management. Cattle under these conditions have reached 9.5 cwt (479 kg) in liveweight at 4 years old and as much as 12 cwt (605 kg) at 6 years old, killing out at 50% of their liveweight.

Productivity parameters of the White Fulani have been compared with data on 12 other indigenous breeds maintained under similar management conditions (ILCA, 1978), showing this breed to be considerably above average for all the main production traits, including calving interval, milk production and growth. In addition, a herd of White Fulani has been kept successfully in a lightly tsetse-infested area at the University of Ibadan farm for many years.

The trypanotolerant cattle can be divided into two main types, the N'Dama and the West African Shorthorns, with a series of intermediate breeding populations. Among these groups, 11 breeds can be recognized in West and Central Africa (ILCA, 1979). Five breeds have also been identified which represent crosses between Zebu and N'Dama or Shorthorn types.

Debate has gone on for some time concerning the productivity of the trypanotolerant breeds, with little precise information available. Summarizing the performance of an experimental Muturu herd kept over the period 1952 to 1956 in the derived savanna zone of Nigeria, Ferguson (1967a) draws attention to their high reproductive capacity and promising beef production potential. However, he also points out that they might not be attractive to local producers because their milk production tends to be low under traditional husbandry conditions. Breeding stock are not readily available, and reproductive performance often appears to be depressed under trypanosomiasis challenge. By 1958, however, the qualities of the Muturu had been sufficiently recognized in Nigeria to prompt the creation of a Muturu 'reserve' area for the maintenance of a pure Muturu population in the southern half of Ondo Province.

Hill reported during the Symposium that the largest N'Dama multiplication herd is kept on the Kolo Ranch in Zaire, with 20 000 head in an area virtually free of tsetse. Under good management, the reproductive performance on this ranch has been satisfactory and any problems involved in transferring animals to areas of higher tsetse challenge have been solved by treating them with trypanocidal drugs for the first few months after they are moved.

Blair Rains also reported during the symposium that by feeding supplementary phosphorus to N'Dama cattle in The Gambia larger animals were produced which were successfully used for draught and milk production. Phosphorus was fed to cows three months before calving and throughout lactation, and the liveweights of the calves and dams at weaning were significantly increased. However, because of the cost of the phosphates, this practise could not be justified economically.

In a recent survey of the use and potential of trypanotolerant livestock in 18 countries of West and Central Africa (ILCA, 1979), 30 situations were identified where sufficient information was available on trypanotolerant cattle to estimate the main production traits under traditional and improved management and various levels of tsetse infestation. The traits evaluated were reproductive performance, cow and calf viability, milk production, growth and cow body weight. These were used to build up an index of total weight of calf plus liveweight equivalent of milk produced annually, both per cow and per 100 kg of cow maintained per year. Thus, production can be related directly to maintenance costs in terms of the number and size of animals which have to be supported. On the basis of these indices, it was shown that the productivity of trypanotolerant cattle per unit weight of cow maintained under light tsetse challenge is only 4% lower than that of Zebu and other indigenous cattle types kept in tsetse-free areas throughout Africa. It was also shown that the productivity of trypanotolerant animals was 30% lower under traditional conditions than with improved management, and that productivity was 27% lower under medium tsetse infestation and 53% lower under high infestation, compared with levels achieved under conditions of light infestation.

These comparisons suggest, first, that the productivity of trypanotolerant cattle relative to other indigenous types may be much higher than previously assumed; second, that, in certain circumstances, plans for increased utilization of trypanotolerant cattle may well be immediately justified; and, third, that more accurate evaluation of productivity is called for in relation to the degree of trypanosome infection.

Although it is difficult to determine the actual productivity of cattle kept in the subhumid zone, figures based on the Nigerian cattle industry as a whole may be reasonable indicators. Van Raay (1975) reports daily milk yields of 0.77 kg per lactating cow, and the Nigerian Livestock and Meat Authority reported in 1971 an average annual offtake of 9 to 10%, with carcass weights averaging 128 kg and a dressing out percentage of 47%. Annual production can probably be estimated reasonably at 35 kg of weaned calf per cow. Even assuming a fair margin for error, these figures indicate an enormous difference between potential and actual productivity, attributable to inadequate management, poor nutrition and disease.

Sheep and Goats

Both the transhumant and sedentarized pastoralists of the subhumid zone keep flocks of sheep and goats, but most of the small ruminants in the area are kept by farmers, villagers and townspeople. These animals are the main source of red meat in the rural areas. In Nigeria, it is estimated that there are about as many sheep as cattle and about three times as many goats. Goats are particularly useful because their ability to browse ensures them an adequate diet in areas where grazing is in short supply, and, though they are not generally milked in West Africa, they can yield half a litre or more a day.

Mason (1951) classifies the hairy, thin-tailed sheep of West Africa as long-legged and dwarf types. There are several varieties of long-legged Fulani sheep, with a number of local names. Their height ranges from 65 to 75 cm at withers. The West African Dwarf sheep, also called Fouta Djallon or Djallonké, occur

throughout the region south of the 14th parallel, kept in small numbers by settled farmers and villagers. They are trypanotolerant and hardy.

West African goats also vary in size from the dwarf variety of the more humid areas to the large animals kept in the semi-desert regions, with a number of intermediate types (Mason, 1951). The West African Dwarf goats correspond closely in name, size and distribution with the West African Dwarf sheep, and they are also trypanotolerant.

The ILCA study of trypanotolerant livestock (1979) included a consideration of the productivity of West African Dwarf sheep and goats. Production information on small ruminants in the region is scarce, but indices were built up for sheep and goats wherever possible, based on the weight of 5-month-old young produced per 10 kg of adult female maintained per year. There were sufficient data to compare indices for sheep in nine locations and for goats in three. The results of the survey suggest that productivity per unit weight of female maintained can well be at least as high for the small trypanotolerant breeds as for a range of other indigenous types in non-tsetse challenge areas throughout Africa. Thus, as in the case of cattle, increased utilization and more accurate evaluation of the productivity of these breeds would appear well justified.

It was not possible to compare the productivity of cattle with that of sheep and goats using the ILCA indices, but the data obtained suggest that small ruminants may be more productive. In an analysis of the economics of pasture improvement and beef production in the subhumid zone of Togo, Doppler (1979) concludes that the cattle available at present are insufficient to utilize the fallow land resources available in the zone. He suggests that the production of sheep and goats, which have much higher reproduction rates than cattle, should be examined as an economically attractive alternative to cattle production. The risks likely to be experienced with local breeds seem acceptable and consumers in many areas prefer sheep and goat meat to beef.

TRADITIONAL LIVESTOCK MANAGEMENT SYSTEMS

Any discussion of livestock production in the subhumid zone must centre on the pastoralist Fulani, since their flocks and herds account for the great majority of livestock in the region. In Nigeria, the transhumant and semi-settled producers provide an annual offtake of about 790 000 cattle.

The pattern of livestock production in the zone has been shaped by environmental and historical factors. Important considerations are the availability of grazing, as determined by soils, climate, fire and cultivation, and the incidence of disease, particularly of tsetse-transmitted trypanosomiasis. Traditional patterns of transhumance have been affected in recent years by the droughts in the Sahel and increased arable farming in the northern areas, as well as by expanding agriculture in the subhumid zone itself. Actual livestock production in the zone is still far below its potential carrying capacity: in Nigeria, where the present cattle population in the subhumid zone is about 2 million, the potential carrying capacity has been estimated at 13.5 million, while the semi-arid zone to the north is considered dangerously overstocked with a cattle population of about 6 million.

Pastoralist groups are often classified according to their livestock production systems into such categories as transhumant, semi-transhumant, semi-settled and settled (see Johnson, 1969; Salzman, 1971; van Raay, 1975). They may also be classified according to their cultural and livestock-rearing practises (see de St. Croix, 1945; Hopen, 1958; Stenning, 1959; van Raay and de Leeuw, 1974), or according to ethnic typologies. Unfortunately, when applied in the field, none of these classification systems produces clear, distinct categories, and they often do not correspond with each other. For example, Dupire (1970) notes:

it is very difficult to apply a classification system to the sedentary and semi-nomadic Fulani (*Fulbe ladde*, *Faxfarou*) of these areas Those of western Niger are not completely settled: their villages are often composed of scattered houses which are easily moved Groups or individuals shift from one type of economy to another.

Moreover, a distinction needs to be made between different types of movement. Transhumance (*kodaɓi*) is the pattern of regular movement between areas according to the season, while migration is a specific movement to a new area. Stenning (1957) describes two types of migration among the Fulani: the migratory flight (*perol*) that generally occurs when political events force a group to flee its traditional territory and take refuge in a new area, and migratory drift (*'eggol*), when a group gradually moves away from its former grazing lands and does not return.

Keeping these reservations in mind, it is possible to classify the Fulani of Nigeria's subhumid zone into four groups on the basis of their livestock production systems. The fully mobile pastoralists practise transhumance, generally moving south during the dry season and north during the rains. This group is widely distributed throughout the savanna regions of Nigeria. Livestock holdings tend to be large: the average family keeps over 80 head of cattle, as a conservative estimate, and about 20 to 40 sheep and goats. Though they recognize larger groupings, such as lineages and clans, the most important units are the household camps and the small groups which move together in the annual pattern of transhumance.

The transhumant pattern is determined by the nutritional and health needs of the livestock and the social and economic needs of the pastoralists. Herds are moved in search of grazing and water, and areas of trypanosomiasis and other disease are avoided. Movement is also determined by the location of farms, which provide stubble grazing, markets and other amenities. The groups tend to move more frequently during the dry season, but they never establish permanent camps, even during the rains. The animals are taken out from the temporary camps to graze during the day and are tethered at night.

The less mobile pastoralists, by contrast, maintain a permanent base camp where a few family members, especially the elderly, and some of the stock, particularly cows in milk, remain all year, while the others move away during the dry season and return during the rains. Although these groups practise some cultivation, livestock production is still their most important economic activity (Awogbade, 1977), and they prefer to hire outsiders to carry out farm work whenever possible. Their herds and flocks tend to be smaller than those of the fully mobile pastoralists, but their animal husbandry practises, forms of economic cooperation and social organization are very similar. Several cases have been recorded of less mobile Fulani groups who have eventually chosen a more settled life-style (Hopen, 1958), and several researchers have claimed that this pattern is an intermediate stage leading to full sedentarization. Once settled, it seems that groups seldom revert to transhumance, although prior to full sedentarization, 'those Fulbe who do not farm ... at any given time will include family households which farmed a year or two previously but were not farming at the moment of enquiry' (Hopen, 1958).

The semi-settled pastoralists keep smaller herds than the two more mobile groups, and agriculture and livestock production are both important economic activities. These pastoralists tend to remain in permanent settlement most of the year, moving with their herds only towards the end of the dry season in search of water and grazing. Like the mobile Fulani, their movements are often from north to south during the dry season, or they may move on to flood plains along rivers, as for example along the Niger River in Kwara State of Nigeria (Adegboye et al., 1978). Temporary shelters are constructed and crops are grown and harvested at the beginning of the rainy season before moving back to the north. In other cases, as in the northern parts of central Africa, crops are planted and cultivated during a prolonged stay on the journey southwards and harvested as the pastoralists return north. These semi-settled pastoralists are not strictly opposed to intermarriage with agricultural groups. For this reason they have often become more integrated into the social and political life of the areas where they live.

The fully settled Fulani remain in permanent homesteads throughout the year. They practise agriculture, with their livestock taken out to graze every day by children or hired herdsmen and penned at night. The category of settled Fulani also includes some who live in urban areas but own herds of cattle elsewhere on an absentee basis.

Settled farmers from other ethnic groups keep livestock farther south in the subhumid zone, usually of the trypanotolerant breeds. Their animals are grazed near the homesteads during the day after milking in the morning, and are usually penned at night, though in some cases night grazing may be practised. In some areas, cattle are left free to wander during the day in the dry season after the crops have been harvested. They tend to move to well watered areas where they graze and water on their own. Calves may be penned during the day and allowed to suckle briefly when the cows return from grazing in order to induce the letdown of milk. During milking, they may be tied to the forelegs of their dams, and then allowed to suckle again after milking. After three months, they are grazed in separate herds, and at six or seven months they are weaned and allowed to graze with the main herd (Oppong, 1971). Sheep and goats are often left to roam freely during the dry season, but are tethered away from the fields once the crops are planted. They are often kept in the family compound at night.

Transhumant Production Systems: Two Examples

Transhumant patterns have been documented in some detail by Hopen (1958) for the Gwandu Fulbe of Nigeria, who move south to the flood plains of the Sokoto River and beyond during the dry season and return north during the rains. From a sample of 100 households, 66 practised some agriculture, while the rest depended entirely on livestock production. These production patterns appear to be fairly independent of the size of household herds. Farming, when it does occur, is on a very small scale and does not require permanent settlement. Small fields are cultivated in the dry-season areas, and millet is harvested early in the wet season using all the family manpower gathered together before the movement back to the north.

The distance covered during the average transhumant cycle is about 240 kms, with approximately one-fourth of the groups moving over 320 kms. The groups move according to certain seasons. During the wet *dungu* season (July to the end of September), scattered pastoralist households come together to form larger camps. These camps move frequently - every 3 to 10 days on average - to avoid insects and disease, soggy ground and possibly cattle tax collectors. Only temporary shelters are erected, made of grass in a beehive shape. Part of the household might remain near these shelters while the boys and young men move the herds around the area in search of grazing. During this season, the Fulani attend local markets to obtain information on grazing conditions, the incidence of disease and the movement of the tax collectors.

As the dry *'yawāl* season begins (October to the end of December), the Fulani move their cattle down the valley of the Sokoto River, stopping along the way to graze crop residues from newly harvested fields. Those Fulani who practise cultivation then return to their own plots, while the others keep their cattle on the fields surrounding local villages in return for token gifts. As the main *dabunde* dry season continues, they tend to move their herds onto the flood plains, where their shelters are simple windcreens. During *ceedu* at the height of the dry season (end of February to the end of April), little milk is available and hunger is widespread. This is the period in which the herds are moved farthest south, to the banks of the Niger River, and pastures are burnt by the local farmers.

The rains begin during *seeto* (early May to June). When planting begins, the herds are moved away from the cultivated areas. Those Fulani who practise agriculture keep their animals nearby until after the millet harvest, while the more mobile Fulani start moving immediately towards the northern wet-season grazing area.

Stenning (1959) describes the transhumant pattern of the Borno Wo'daa'be Fulani in Nigeria who move between the Gana River in the north, the central Fune-Damaturu area, the Gujba plains and the Biu foothills in the south. These Fulani move according to a lunar cycle:

in which the auspicious days for moving camp occur three times weekly. Camp is therefore pitched in one spot for three days, at another for two days, and at yet another for two days, until the final four days of the month are reached when no move is made until either the new moon has been seen or ... a consensus of opinion among elders ... fixes the start of the new pastoral month.

The pattern of transhumance was recorded for a sample of 168 households. The majority of groups spend the wet season in the central Fune-Damaturu region and begin moving south in November, shifting camp about every six days. By January, they reach their dry-season grazing areas on the Gulba plains. Here, the camps are situated near sources of water, rather than near grazing, and the cattle have to travel long distances from the camps to their pastures, losing condition in the process. The grazing periods are interrupted, generally twice a day, to take the cattle back to be watered. Watering during this season also requires considerable labour.

As the dry season continues, the animals are dispersed in small herds to take the fullest advantage of the remaining grazing. When the first rains come, the pastoralists await news from the north: they normally only begin moving their herds when they have reliable information that the rainy season has actually begun, generally in July. During the wet season, they shift camp frequently to avoid muddy conditions, but generally move only short distances. The women, in particular, prefer to remain close to villages where they can sell their milk and butter.

A second pattern of transhumance occurs among other Fulani groups of the same lineage. These pastoralists move north during the dry season, digging shallow wells in the bed of the Gana River. When new grass is reported in the wet-season grazing area, they move back south.

A special situation is also reported from Cameroon where transhumant movement occurs in response to topographical conditions. During the rainy season, the lowland plains become flooded, restricting grazing to the plateau areas. As the dry season progresses, the quality of the grasses on the plateaux declines and the animals are brought down to lush pastures on the flood plains.

A Model of Livestock Production in the Subhumid Zone

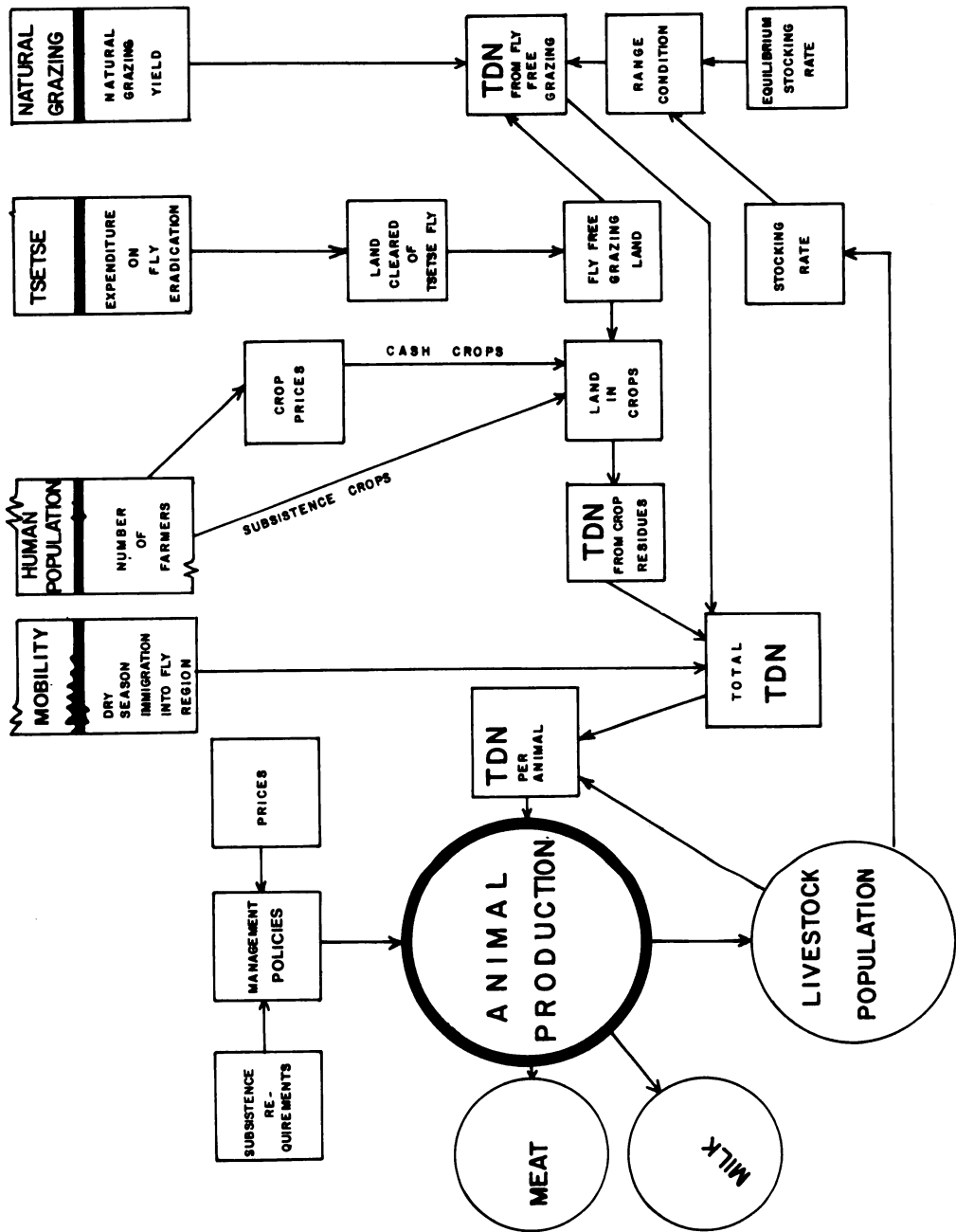
Figure 5 presents a basic schematic model of livestock production in the subhumid zone, derived by von Kaufmann from simulation work on the agricultural sector in Nigeria carried out by a team from Michigan State University (Johnson et al., 1971). The model shows the linkages between the most prominent features of the production systems of the zone, with the level of total digestible nutrients (TDN) taken as the principal factor constraining production, though this, in fact, has yet to be proven. Changes in variables can be worked through the model to reveal their effects on such factors as production, farm income and foreign exchange earnings. The sensitivity analysis conducted by the Michigan State University team strongly suggests that more significant changes in livestock production are likely to be induced by changes in animal nutrition levels than by any other factor.

The total digestible nutrients (TDN) available to animals kept under the traditional livestock production system appear to be a function of four main factors: the quantity and quality of natural grazing available, the level of tsetse infestation and the degree of trypanosome infectivity, the size of the human population and the level of subsistence and cash cropping, and the degree of mobility which determines the availability of grazing during the dry season. These four factors are depicted across the top of Figure 5, along with the links to the two sources of feed available to traditional pastoralists, natural grazing and crop residues.

The TDN available from natural grazing is basically a function of the area of grazing available and the herbage yield per ha. In Nigeria, de Leeuw (1978a) estimates that the natural grazing available in the subhumid zone extends over an area of 450 000 km². Given a fairly conservative estimate of annual herbage yields of 4 to 6 tonnes DM per ha, this area could support about 13.5 million cattle, which is probably more than the present total cattle population of the country.

Not all the potential grazing land in the subhumid zone can be safely used by livestock producers, however, because of the risk of trypanosomiasis in areas which are infested by tsetse. Nevertheless, during the dry season the low ambient

Figure 5. A model of traditional livestock production in the subhumid zone



Source: Derived by von Kaufmann from Johnson et al. (1971).

humidity and the reduction in shade from trees and shrubs drive the tsetse flies into those restricted parts of the environment which offer more shade and moisture. The riverine tsetse species retreat to streams and drainage lines where there is surface water and a relatively dense tree canopy. The savanna species move to shaded 'islands', particularly patches of *Isobberlinia doka* or riparian woodland. Thus the transhumant pastoralists are able to utilize a larger proportion of the sub-humid zone precisely at a time when grazing is scarce in the drier areas to the north. In some parts of the zone, land has also been freed of tsetse by government clearing and spraying programmes and is safe for grazing on a year-round basis. The amount of land freed in this way is a function of government development priorities and the resources available, but not all of this land necessarily becomes available for grazing: a significant proportion is taken up for arable farming.

The amount of crop residues available for grazing is determined by the types of crops grown, the relationships between pastoralists and farmers and the amount of land under cultivation, which in turn is a function of the number of people cropping for subsistence and the level of cash cropping. As there are few purchased inputs and yields tend to be static, the level of cash cropping is a function primarily of the producer prices obtained. There is also competition for crop-residue grazing between the sedentary pastoralists and the transhumant producers who pass through the crop lands during their southward movement after the harvest season.

Whatever the total primary production and the level of available TDN, secondary production of the animals themselves is also a function of the management system employed. Management is determined to a considerable extent by the specific aims of the animal producers. In traditional animal production systems, the subsistence and security of the herd-owners are of paramount importance, though producer prices also influence management decisions to some extent. At present, milk rather than meat appears to be the most important product of the system, both for the sustenance of the livestock producers and their dependants and as a source of cash income used to purchase grain and other items. The second production goal is the maintenance and increase of the herd, as this is necessary for maximizing both subsistence and income. Large herds also serve as a buffer

in case of losses from disease or drought. Sales of stock are also important to the economy of all pastoralists, but there is little evidence that cattle are maintained in any special way with a view to maximizing meat production.

One of the most important features of livestock production in the subhumid zone is that virtually the entire industry fits into this traditional production model. In spite of government efforts over many years, production based on grazing reserves, ranches, feedlots and dairy farms has never reached significant levels. This experience suggests that improvements in the system, if they are to bring about significant change, will have to be directed towards the existing traditional producers rather than trying to introduce totally new forms of production.

Sheep and Goat Production

It is generally recognized that more attention should be paid to sheep and goat production, but little concrete information is available to suggest strategies for increasing the productivity of these species. Sheep and goats, to some extent, can make use of forage not used by cattle, and they fill a different niche in the subsistence strategy of pastoralists and farmers. In Nigeria, for instance, the annual offtake rate for sheep and goats is about 45% and they contribute about 30% of total meat consumption.

The disease and nutritional problems of sheep and goats merit increased attention. In Senegal, disease problems include coccidiosis and helminthiasis, and the animals lose weight during the dry season. They are also affected adversely by a mould which grows on the grass at the beginning of the rains. In Togo, government policy is to encourage sheep and goat production to meet human nutritional needs. Farmers are encouraged to keep small flocks, and there is a law against slaughtering females under eight years old, though this has proven impossible to enforce.

IMPROVED ANIMAL FEEDING

The low quality of natural savanna grazing, particularly during the dry season when the crude protein content of the grasses may be as low as 2%, suggests the potential role of supplementary feeding with concentrate mixtures rich in protein. A sensitivity analysis by Johnson et al. (1971) indicates that improved feeding will have a greater impact on livestock production than any other management strategy, while comparisons of various feeding strategies carried out by de Leeuw and Agishi (1978) suggest that the most attractive approach in economic terms would be natural savanna grazing with supplementation (see Table 11). Thus, the possibilities for supplementary livestock feeding in the subhumid zone merit further discussion.

Under present conditions, there is little likelihood that traditional livestock producers will be able to generate sufficient financial resources on their own to provide supplements to their herds. The supplementary feeding which has been carried out in the region to date has been provided through government agencies.

A supplementary feeding project was initiated in northern Nigeria in 1962/63 under the Fulani Amenities Programme in order to reduce weight loss in cattle during the dry season. Supplements were provided at the outset on a wholly subsidized basis, with the intention of gradually phasing out the subsidy element over a six-year period (Ogunfowora et al., 1975). During the first year, the project was limited to Adamawa Province and the Zaria and Katsina areas, but during the second year it was expanded to include Bornu and Plateau Provinces. With the creation of states in Nigeria in 1967, each of the new states launched a supplementation project. The recent Sahelian droughts, which led to a drastic reduction in available herbage and loss of livestock, emphasized the value of supplementary feeding, and the project was expanded considerably. For instance, in the former North Eastern State only 290 tonnes of cottonseed were distributed to livestock producers in 1970/71, whereas by 1974/75, 3 949 tonnes of supplementary feed were distributed, composed of cottonseed, groundnut cake, dried brewer's grains and *gawo* pods (fruit of *Acacia albida*).

The optimum amount and composition of supplementary feeds has never been determined because knowledge of animal nutrition requirements in the tropics is still deficient. The project in Nigeria aimed at providing 0.5 to 1.5 kg of supplement daily for each animal throughout the dry season. It was estimated that this level of supplementation would enable the animals to maintain the weight they had reached at the end of the rains. Rations originally consisted of equal parts of groundnut cake and cottonseed plus 2% salt. As demand for the supplements soon exceeded supply, new feeds were introduced: *gawo* pods around Maiduguri and groundnut tops in Sokoto (Ogunfowora et al., 1975).

The project has suffered from serious problems, due primarily to an inadequate transport system, lack of storage facilities, insufficient personnel to handle the procurement and distribution of feeds, profiteering by unscrupulous businessmen and restrictive government financial controls which have led to sporadic feed shortages. The quantities of feed provided, totalling about 10 400 tonnes in 1974/75, have been very small compared with the requirements of the national livestock population during the six-month dry season from December to June. It has been estimated that the total supplementary feed requirements for cattle, sheep and goats in Nigeria may be well over one million tonnes per annum, with feeding periods varying from 30 days at the eighth parallel to 7.5 months above the 13th parallel. Given the insufficient quantities of feed provided, the impact of this project on the traditional livestock production system has been limited, particularly as a considerable proportion of the feed available has been allocated to government farms and commercial cattle ranches.

There is no record that this project was ever subjected to economic analysis, though the costs have proven to be substantial. Partly, this is because many ingredients of supplementary feeds have to be imported, particularly vitamin and mineral supplements. Although it is clear that supplementary feeding leads to improved animal performance, the costs and benefits need to be better understood, and opportunities need to be investigated for the increased use of local feeds.

Another possibility for improved livestock feeding would be management systems which allow animals to graze for longer periods of the day. Whereas traditionally herded cattle rarely graze more than eight hours a day, cattle allowed to graze freely in paddocks graze from nine to ten hours. In addition, herded cattle graze mostly during the hottest time of the day, while paddocked, unherded cattle graze mostly during the cooler parts of the day and often into the night. De Leeuw (personal communication) found that 20 to 35% of the grazing of unherded cattle occurred between 18.00 and 06.00 h, which suggests that the provision of night grazing could increase liveweight gains considerably. Strategies for increasing grazing time could also be combined with various programmes for pasture improvement, as described in the chapter on fodder resources and pasture management.

6.

ANIMAL HEALTH

CATTLE DISEASES

The major disease risks to cattle in the subhumid zone have long been recognized as rinderpest, trypanosomiasis, contagious bovine pleuropneumonia (CBPP) and dermatophilosis (streptothricosis). With the development of a tissue culture vaccine for rinderpest and a fairly effective freeze-dried vaccine for CBPP, tsetse-transmitted trypanosomiasis has remained the major development constraint, restricting the use of much of the subhumid zone by cattle, and to a lesser extent by sheep and goats. As such, it will be treated in a separate chapter of this report.

In addition to the major diseases, tick-borne diseases are common and heartwater in particular takes a heavy toll of susceptible animals. Several of the endemic bacterial diseases, e.g., brucellosis and tuberculosis, could assume greater importance as husbandry systems become more intensive, as could parasitic gastroenteritis which already takes a heavy toll whenever ruminant livestock are concentrated on wet pastures. On the other hand, increased sedentarization should limit the wide dispersal of many infectious diseases, and changes in production systems should affect the incidence of nutrient deficiencies and metabolic disfunctions.

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- a. Based on papers presented by W Ferguson and A A Ademosun and discussions led by D H Hill.

In francophone countries, many diseases are controlled by vaccines provided free to the livestock owners by the national governments. However, drugs such as anthelmintics have to be paid for by the producers, so the economic justification for such treatments must be considered at the producer level as well as at the national level when planning animal health programmes. For example, their costs might be justified for the treatment of young stock, but not for adult animals. Similarly, the cost of chemoprophylactics for trypanosomiasis might be kept to a minimum by treating only the most vulnerable livestock populations.

In general, money for veterinary treatment might be more wisely invested in improved animal feeding. Yet large sums are often allocated for veterinary drugs in cattle production projects without clearly specifying the local disease problems. Similarly, although most small-ruminant diseases have been identified and described, little is known of their relative importance or the cost/benefit ratios of veterinary treatment. As a result, it appears that too much is being spent at present on veterinary drugs. Important topics requiring further research include the relative importance of different animal diseases, the interaction of disease with nutritional status and other factors, and the seasonality of disease incidence.

Rinderpest

Rinderpest first appeared in the subhumid zone between 1890 and 1900. The disease is caused by a highly infectious virus producing a febrile, catarrhal condition with inflammation of the mucous membranes. Lacrymation, becoming mucopurulent, is the usual first sign of the disease. Inflammation of the buccal mucosae gives rise to necrotic areas of the gums producing a cheese-like material and a characteristic smell from affected animals. Diarrhoea, and even dysentery, follow with a high mortality in susceptible animals.

In some instances, mortality rates as high as 90 or 100% were recorded from the 1890s to the 1920s in parts of West Africa. The seriousness of losses from rinderpest led to the establishment of the Veterinary Research Laboratories at Vom

in Nigeria in 1924, where virulent virus and hyperimmune sera were prepared for use in immunization campaigns according to methods which had been developed in Kenya and India.

The virus/serum double inoculation method (DI) of immunization was highly effective, though at a cost of a 3 to 5% mortality rate amongst vaccinated cattle. It was followed in the 1940s by the use of an attenuated goat-adapted virus vaccine which was as effective as the DI method and much safer, mortality on the average being below 1%. However, these vaccines never reached more than 30 to 40% of the cattle population and there was always a residual pool of susceptible unvaccinated animals, usually under three years old. Rinderpest continued to occur until a major international eradication campaign was decided upon through the Organization of African Unity (OAU). This was the 15th joint international action sponsored by the OAU and hence was called Joint Project (JP) 15. Vaccinations were carried out for three full years, from 1962 to 1965, reducing the disease to occasional sporadic outbreaks.

When rinderpest was prevalent, the highest incidence of the disease was in the Sudan and Sahel zones. Rinderpest also occurred sporadically in the subhumid zone, though its incidence was restricted by the relatively low cattle numbers, due to the prevalence of trypanosomiasis. In forest areas it was introduced to the susceptible trypanotolerant population by trade cattle moving towards the southern markets.

The present tissue culture vaccine is safe and effective for all breeds and classes of cattle, but the current danger is that the dramatic reduction in the incidence of the disease will generate complacency and premature relaxation of vaccination programmes. Inadequate maintenance of immunity after the JP 15 campaign could all too easily lead to bigger rinderpest outbreaks than those experienced in the past, particularly where more intensive production systems and concentrated livestock populations have been established.

Contagious Bovine Pleuropneumonia

Contagious bovine pleuropneumonia (CBPP) is caused by the organism *Mycoplasma mycoides* which affects the lungs and pleura causing a lobular pneumonia and sero-fibrinous pleurisy. The course of the disease is seldom acute: it is usually insidious and slow, with few clinical symptoms at the outset to enable early recognition. CBPP spreads through inhalation of infected droplets in the breath of infected animals. Morbidity and mortality can be high, although it may take many months for infection to spread amongst animals in a herd. Chronically ill animals may live for a long time, and some recover but retain necrotic sequestra in their lungs which can break down at any time under stress and renew the infection. Post-mortem lesions of lobular pneumonia, red and grey hepatization with distended septa ('marbling') and much sero-fibrinous pleural exudate, and even strong fibrinous attachment between parietal and visceral seral mucosae, are diagnostic.

The incidence of CBPP persists in most West and Central African countries in spite of the development of effective freeze-dried vaccines. The FAO/WHO/OIE *Animal Health Yearbook* for 1977 indicates a low sporadic incidence of the disease in Senegal, Guinea and Sierra Leone, a moderate incidence in Chad, Upper Volta and Nigeria and a higher incidence in Mali, Ivory Coast and the Central African Empire. In Niger, Togo, Benin, Nigeria, Cameroon and Central African Empire, the disease is said to be confined to specific regions.

Given the persistence of CBPP, the incidence of this disease could rapidly revert to serious proportions if control measures were to become relaxed. However, there is now growing confidence in prospects for its satisfactory control, largely due to the availability of an effective and stable vaccine based on the strain *Mycoplasma mycoides* T₁ 44, which appears to confer an immunity lasting more than 12 months (Lindley, 1978). There is also evidence that this vaccine, if used correctly over a period of years, could lead to the elimination of the disease altogether. The use of this vaccine, combined with the control measures recommended by the FAO/OIE/OAU Expert Panel on CBPP in 1971, has been made the basis of an International Campaign for the Eradication of CBPP in West Africa.

The T_1 vaccine is inoculated into the tip of the tail and sometimes, particularly if inoculation techniques are faulty, causes severe reactions which may result in the loss of part, or all, of the tail. This can discourage cattle-owners from taking their animals to immunization camps and, as the animals are normally vaccinated for rinderpest at the same time, there is a risk that cattle owners' rejection of CBPP vaccine will lead to an increase in the number of animals susceptible to rinderpest as well (Chalmers, 1975).

In general, however, where adequate supplies of T_1 vaccine are available to a mobile and competent veterinary service, the prospects for control of CBPP are favourable. This disease is therefore no longer considered a major deterrent to the development of more intensive livestock production systems in the subhumid zone.

Brucellosis

Brucellosis in cattle is caused by the bacterium *Brucella abortus* which affects the reproductive tract. It causes abortion in the second half of pregnancy due to inflammation of the cotyledons and placenta. Infection is commonly spread through affected foetal membranes and uterine exudates, but can also be transmitted by an infected bull at service. Diagnosis may be made by isolation of the organism from an aborted foetus or foetal membranes, or serologically from the dam.

Insufficient is known about the incidence of brucellosis, though the disease appears more widespread among settled cattle than in mobile herds and it is more common in some areas than in others. Brucellosis may be more common in the subhumid zone than in the drier areas to the north, and the incidence of the disease may increase substantially, along with abortion rates, if large numbers of animals are introduced into the zone.

Brucellosis is also a zoonosis: people are affected by the disease when they consume milk from infected cows. However, most milk in the subhumid zone is

soured before it is consumed and souring kills *Brucella* (Eze, 1977), so the human population is generally not at great risk.

Dermatophilosis

Dermatophilosis, formerly known as streptothricosis, is one of the most important cattle diseases in West Africa from an economic standpoint, although it has been the subject of relatively little research. It is caused by the organism *Dermatophilus congolense* and can also affect sheep and horses, though in West Africa it usually only affects cattle. The organism can be isolated from the skin of cattle showing no clinical signs; it requires some triggering mechanism to become pathogenic and start growing in the dermis. This mechanism might be a scratch or insect bite penetrating to the dermis or continuous or repeated wetting which softens the epidermis. This causes a chronic local dermatitis with proliferation of the epidermis and a serous exudate which gives rise to small raised patches of skin and matted hair in 'paint brush' fashion. Lesions commonly occur first in the perineal region or on the udder, on the back near the hump, on the rump or on the hind legs. Lesions may increase in size, producing hard plaques of debris and matted hair with painful inflamed areas underneath. They may gradually extend over the body and in serious cases cover most of the skin, interfering with its function and sometimes leading to death. The symptoms do not normally progress to this extent in Zebu cattle, but chronic infections can greatly impair the condition of an animal, causing emaciation, lowered productivity and a greatly devalued hide. In addition to economic losses in breeding herds, there is evidence that the disease interferes with marketing efficiency.

A conference on dermatophilosis was held in Ibadan, Nigeria in 1973, which emphasized the limited contribution of past research. Research has tended to concentrate on the possible role of ticks in transmitting *Dermatophilus congolense* or triggering a change in the organism from skin commensal to pathogen by causing local host tissue damage (Zlotnik, 1955; Plowright, 1956). The possible role of high environmental humidity has also been investigated (McAdam, 1961).

Although associated in the literature with the wetter tropical regions, dermatophilosis occurs more frequently in Nigeria in the drier northern zone. It is seldom seen among the trypanotolerant West African Shorthorn cattle of the derived and lowland rainforest, and it has been suggested that these breeds have a level of resistance to the disease. In the northern areas, the disease appears more frequently during the rainy season, though there have been insufficient studies of its epidemiology in the field under traditional husbandry conditions. Some individual animals seem to be resistant, while others in the same herd are highly susceptible, though occasional inspections are inadequate to reveal why this should be so. Spontaneous cures occur in many cases, following the cessation of the rains, but it is not known what proportion represents permanent recoveries.

Exotic stock are particularly susceptible to dermatophilosis, which can lead to severe debilitation and often death. First generation crosses with exotic stock are also more susceptible than local animals. An outbreak at the University of Ife farm in Nigeria, for example, during the rainy season of 1978, caused heavy losses among the Friesian/Holstein, Brown Swiss and Jersey cattle, while the White Fulani were hardly affected.

Tick-Borne Diseases

Tick-borne diseases, such as anaplasmosis, babesiosis and heartwater, are assuming greater importance in West Africa, especially in areas where exotic cattle have been imported in substantial numbers and where management systems are becoming more intensive (FAO, 1977a).

Anaplasmosis or gall sickness, caused by the protozoa *Anaplasma marginale* in cattle and *A. ovis* in sheep and goats, causes a low-grade fever with anaemia, loss of appetite, eventual emaciation and sometimes death. Babesiosis, also called piroplasmosis, redwater or tick fever, is caused by *Babesia bovis* and *B. bigemina* in cattle and *B. ovis* in sheep. It is a febrile disease characterized by anaemia and jaundice, and abortion in pregnant animals. Mortality is not high, but full

recovery from debility and anaemia takes a long time. *Cowdria* (*Rickettsia ruminantium*) affects cattle, causing fever, nervous symptoms and excess pericardial fluid which gives rise to its common name of 'heartwater'. Mortality occurs fairly frequently, particularly among exotic cattle.

Although exotic animals are not likely to be imported into the region on a large scale for some time, sedentarization and more intensive production systems based on indigenous animals can be expected to lead to increased incidence of tick-borne diseases, as well as mechanical damage to teats and perineal regions caused by ticks. More research is needed within the region on the biology, ecology, host relationships, population dynamics and disease relationships of the most important tick species: *Boophilus annulatus*, *B. decoloratus*, *B. geigyi*, *Amblyoma variegatum* and *Hyaloma* spp.

An undefined *Theileria* problem has also been recognized in the region (Mussman, 1978), probably caused by pathogenic *Theileria mutans*, so that the characterization of cattle *Theileria* in West Africa now requires urgent study (FAO, 1977c).

Parasitic Gastroenteritis

Infestation by intestinal worms causes anaemia, trace mineral deficiency, irritation of the gut, toxin production, impairment of protein digestion and poor utilization of nutrients. This leads to progressive weight loss and even death, particularly in young animals. Infestation is more serious during the rainy season. The most common genera of nematodes causing this condition are *Trichostrongylus*, *Ostertagia* and *Haemonchus*.

The extent of losses suffered as a result of worm infestation is often underestimated. These are particularly serious in areas where anthelmintic drugs are used irregularly or not at all and where cattle converge at watering points.

Other Viral Diseases

Foot and mouth disease occurs throughout the subhumid zone, but it is not of major importance in extensive production systems. Whenever more intensive production is introduced, however, the detection and control of foot and mouth disease will become more important.

Other potentially dangerous viral diseases known to exist in West Africa include Rift Valley fever (Ferguson, 1959; Kemp et al., 1973). Highly virulent outbreaks of this disease occurred in Sudan and Egypt in 1976 and 1977. A slow wave of lumpy skin disease has also affected animals in West Africa in recent years, originating in East Africa and progressing through Somalia, Ethiopia and Sudan.

Reproductive Disorders

Low reproductive performance is a widespread problem throughout West Africa, although satisfactory reproductive performances are occasionally recorded, for instance among trypanotolerant Muturu herds (Ferguson, 1967b). The relatively late age at first calving and long calving intervals of the Zebu breeds lead to low calving rates. In some herds, abortion rates are also high. Reproductive performance appears to be lowered by disease and nutritional deficiencies, as shown by Pullan on the Jos Plateau (1978). Pockets of high brucellosis incidence have been identified, and leptospirosis, trichomoniasis and vibriosis also lower reproductive performance, though their extent is not known. Mineral deficiencies, in particular an inadequate intake of phosphorus, are also likely to play a role in poor reproduction, as does sub-acute or intermittent trypanosomiasis. These factors all need closer study.

SHEEP AND GOAT DISEASES

One of the most serious diseases affecting sheep and goats is the rinderpest-like disease observed in many areas of West and Central Africa, referred to variously as *peste de petits ruminants* (PPR) or stomatitis pneumoenteritis complex (SPC). This disease has been responsible for heavy losses, particularly among young animals and in the wetter areas. In Nigeria, it is characterized by ulcerative stomatitis, pneumonia and enteritis, resulting in severe diarrhoea.

Some research workers originally hypothesized that PPR was caused by a rinderpest virus adapted to small ruminants, or perhaps that a caprinized rinderpest vaccine, widely used in West Africa before the introduction of tissue culture vaccines, might have escaped and established itself in small ruminant populations. Ali (1973) reported that a concentration of cattle, sheep and goats around the Rahad River in Sudan during the dry season led to a rinderpest outbreak among all three species. However, the situation has been clarified by studies performed on PPR virus isolates by Gilbert and Monnier (1962), Bourdin and Laurent-Vautier (1967), Laurent (1968), Hamdy et al. (1975, 1976) and Gibbs et al. (1979). This work has clearly indicated that the PPR virus is a paramyxovirus, a fourth and new member of the genus *Morbillivirus*, though closely related to the rinderpest virus. Small ruminants inoculated with tissue culture rinderpest vaccine have been shown to develop an immunity to PPR.

Sheep and goats are also severely affected by parasitic gastroenteritis. Fabiye (1973) studied seasonal fluctuations of nematode infestations in goats in the Zaria area of Nigeria over a year and found increased infestation during the wet season. High counts of *Haemonchus* and *Strongyloides* were recorded at the beginning of the rains, while high counts of *Gaigeria*, *Oesophagostomum* and *Trichostrongylus* were recorded later in the season.

Trypanosomiasis affects sheep and goats, though the dwarf breeds of the coastal belt and the southern parts of the subhumid zone enjoy a degree of trypanotolerance. Isoun and Anosa (1974) examined the effect of experimental *T. vivax*

infection on the reproductive organs of sheep and goats and presented data which indicate that trypanosomiasis has a serious effect on reproductive performance.

Both sheep and goats are also affected by bacterial pneumonia and other respiratory diseases. Goats suffer from contagious caprine pleuropneumonia, while sheep in particular are affected by foot-rot especially during the rains, sheep pox and contagious pustular stomatitis.

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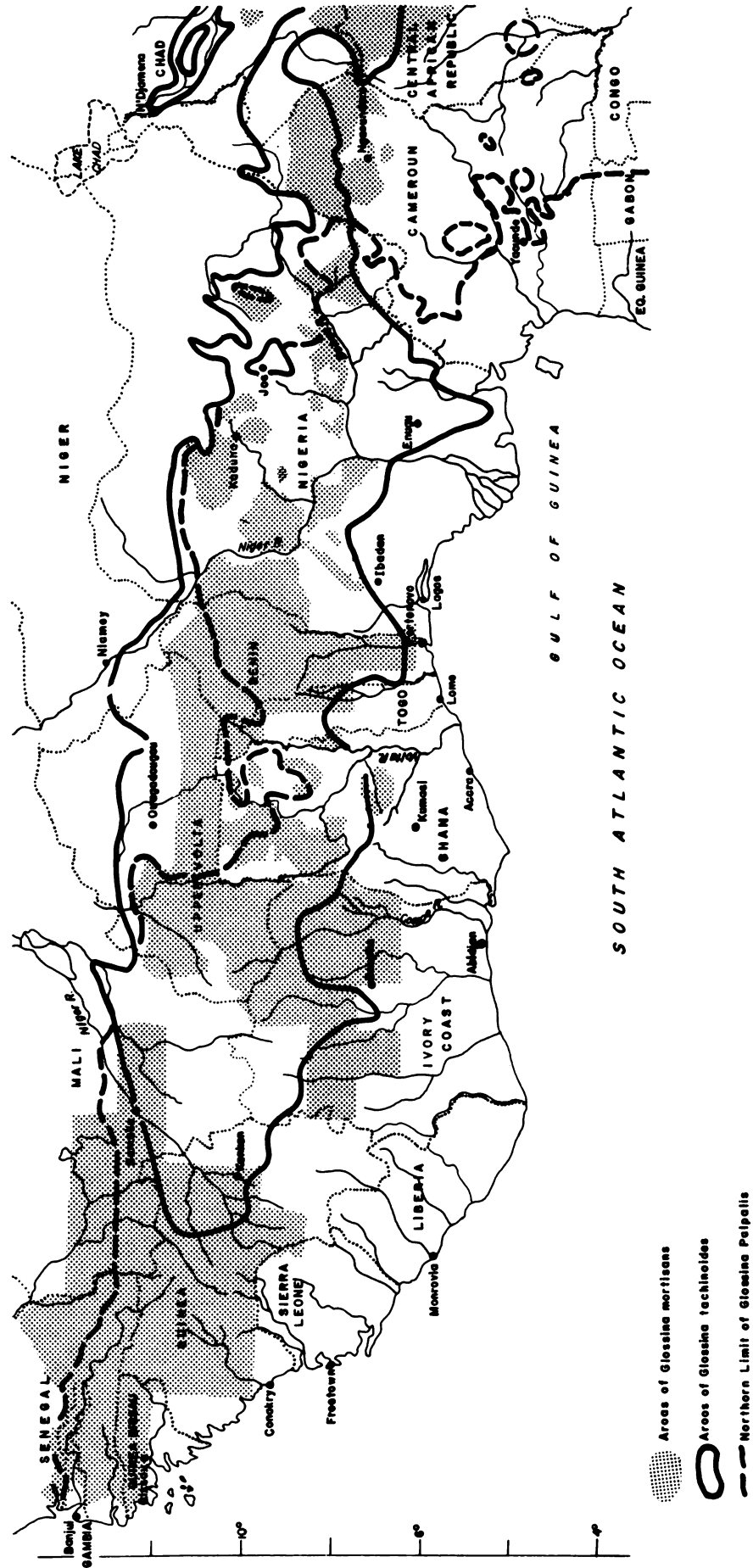
7. TSETSE-TRANSMITTED TRYPANOSOMIASIS *

The entire subhumid zone as defined for the purpose of this report, is infested, or potentially infested, with tsetse flies, except for a few small high-altitude areas. These flies are the biological vectors which transmit several species of trypanosomes, causing human sleeping sickness and trypanosomiasis in domestic livestock. Although there are other constraints and other disease problems in the subhumid zone, tsetse-transmitted trypanosomiasis, accompanied in some areas by onchocerciasis, must be viewed as one of the major impediments to intensified livestock production. Tsetse flies infest approximately one-third of the African continent, or roughly 10 million km², out of which 7 million km² could profitably be used for livestock production (see Figure 6). Based on projected stocking rates, the potential production of about 120 million head of cattle is foregone (FAO, 1977c). Some of the best watered and most fertile land in West Africa is affected; a large proportion could be used at once by pastoralist livestock producers with practically no other development inputs if it were cleared of tsetse (MacLennan, 1979).

* Based on papers presented by K J R MacLennan, S N H Putt, B K Na'isa and S M Touré and discussions led by H E Jahnke.

Figure 6. Tsetse distribution in West and Central Africa

DISTRIBUTION OF TSETSE



Derived from OAU/STRC map THE DISTRIBUTION OF TSETSE FLIES IN AFRICA 1973

Source: Prepared by A Blair Rains.

THE PROBLEM

The Tsetse Population

Tsetse flies of the subhumid zone are usually classified taxonomically into three types: the forest species, primarily *Glossina fusca*, *G. nigrofusca* and *G. medicorum*; the riverine species, mainly *G. palpalis* and *G. tachinoides*; and the savanna species, primarily *G. morsitans* and *G. longipalpis*. A more complete list of tsetse species is given in Table 15. Although these groups are described in terms of their most usual habitats, riverine tsetse may also be found in woodlands and other non-riparian habitats in the higher-rainfall areas and the forest species are occasionally found in patches of relict forest which occur frequently in parts of the derived savannas of the subhumid zone (Keay, 1953, 1959; OAU/STRC, 1973). Sleeping sickness is transmitted by riverine tsetse, while all three types transmit animal trypanosomiasis to a greater or lesser extent.

There are important local seasonal fluctuations in tsetse populations in areas which have pronounced wet and dry seasons. During the dry season, particularly if it is hot, there is a general regression of tsetse flies. This is also encouraged by traditional grass burning among hunters, farmers and pastoralists of the subhumid zone, which reduces the tree and shrub cover that forms the fly's natural habitat.

Long-term fluctuations in tsetse populations, particularly of the savanna type, also occur over wider areas (Ford, 1971). There was a widespread retreat of savanna tsetse towards the end of the last century when the host populations were sharply reduced by rinderpest panzootics, though much of the area freed of tsetse at that time has since been reinfested. Small-scale local reductions have also occurred as a result of increased cultivation and bush clearing or government tsetse eradication projects (Aiyedun and Amodu, 1976; Lester, 1945). However, in many areas the introduction of domestic livestock, notably cattle and pigs, has resulted in expansion of the tsetse population due to the new source of food. The habitat can also become more suitable for tsetse flies whenever overgrazing leads to increased

Table 15. Species of tsetse (*Glossina*)

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1. Savanna tsetse: *morsitans* group, sub-genus *Glossina*
Savanna: *G. morsitans*^a, *G. swynnertoni*, *G. longipalpis*^a
Savanna and thicket: *G. pallidipes*
Evergreen thicket: *G. austeni*
 2. Riverine tsetse: *palpalis* group, sub-genus *Nemorhina*
G. palpalis,^{ab} *G. fuscipes*,^a *G. martinii*, *G. quanzensis*, *G. caliginea*,^a
G. pallicera,^{ab} *G. tachinoides*^a
 3. Forest tsetse: *fusca* group, sub-genus *Austenina*
Rain forest: *G. tabaniformis*,^a *G. nigrofusca*, *G. haningtoni*, *G. nashi*
Forest edge: *G. fusca*,^a *G. medicorum*,^{ac} *G. fuscipleuris*,^a *G. schwetzi*,
G. severini, *G. vanhoofi*
 4. Others *G. brevipalpis*, *G. longipennis*
-

- a. Present in the subhumid zone.
- b. Challier suggests that *G. palpalis* and *G. pallicera* should also be included as forest species.
- c. Challier suggests that *G. medicorum* is found in riverine areas in the savanna zone.

Source: MacLennan (1979).

bush infestation. The introduction of certain types of arable agriculture can also lead to increased tsetse infestation and outbreaks of trypanosomiasis. Habitats for the riverine species are found in mango groves and areas where guava, cashew, cocoa, banana and sugarcane are cultivated, while trees and hedges planted around family compounds and coco-yam plots may also harbour tsetse colonies (Baldry, 1969a; Challier, 1973; Touré, 1974).

Since 1952, *G. morsitans* advances in the central and eastern parts of northern Nigeria have covered at least 25 900 km². Similarly in central Cameroon, an advance of *G. morsitans* has occupied about 20 860 km² of valuable agricultural land since 1950 and, unless halted, is likely to extend considerably further. Consequences for the rural economy have been serious: transhumant livestock producers are forced to move away, contributing to increased grazing pressure in the remaining tsetse-free zone, and the settled agricultural population is impoverished.

These instances of reinvasion and orientation to a man-made environment point to the fact that tsetse eradication in the subhumid zone is not likely to be accomplished by increased settlement and agricultural activity alone without specific eradication programmes. The problem is likely to assume increasing prominence in the future.

Sleeping Sickness

In humans, the prevalent form of trypanosomiasis in West Africa is Gambian sleeping sickness, caused by *Trypanosoma gambiense*, which is transmitted by infected riverine tsetse. Savanna tsetse have never been directly implicated in an outbreak of Gambian sleeping sickness, though their possible role has been suggested by several authors (Duggan, 1962; Ford, 1971).

Not all riverine tsetse populations harbour trypanosomes pathogenic to humans. The disease must be introduced to a fly community through an external source which, it is generally thought, can only be an infected person. There is circumstantial evidence indicating an alternative reservoir host (e.g. Molyneux, 1973; Scott in Mulligan, 1970), but none has so far been positively identified in the field. Once the disease is introduced into a community, it is transmitted from person to person through the infected flies. The chief factor governing the incidence of the disease is the intimacy of contact between tsetse flies and the human population: epidemics have occurred with very low overall densities of tsetse infestation, but where the localized communities of flies have been living and feeding in close contact

with the human hosts (Nash, 1944, 1958 and in Mulligan, 1970).

Gambian sleeping sickness can occur in many forms, ranging from a chronic debilitating condition to a more acute illness. Both frequently proceed to neurological involvement, causing the syndrome which gives the disease its name and usually results in death. With the chronic form of the disease, the principal cause of death eventually is often another disease contracted because of the patient's lowered resistance (Lester, 1945).

Sleeping sickness is found principally in agrarian communities or among groups of people who work or live near rivers and come in close contact with tsetse flies. The pattern of the disease varies considerably in different areas, existing at low levels or in epidemic proportions in its chronic or acute form (Duggan, 1962). The substantial spread of this disease in the 1920s and 1930s gave rise to the first tsetse eradication programmes in West and Central Africa. Due to vector eradication, combined with continuous surveillance, chemoprophylaxis and treatment, the disease at the moment is successfully suppressed in the subhumid zone, though scattered episodes continue to occur. At present, 50 to 100 cases are recorded in Nigeria every year.

In spite of the present recession, however, continuous vigilance is required to keep sleeping sickness at a low level (Thomson, 1968). As already mentioned, disease problems will not automatically be eliminated with increased human settlement: in many parts of the subhumid zone, sleeping sickness has even become an urban problem (Baldry, 1969a, 1970; Challier, 1973; Touré, 1974). For example, riverine tsetse have found a suitable habitat in Bamako, Mali in the extensive mango plantations near the town, and sleeping sickness can only be kept under control by continuous efforts. In Ivory Coast and Cameroon, cocoa and coffee plantations established in the moister parts of the subhumid zone have led to major sleeping sickness outbreaks which have only been brought under control with considerable difficulty and at substantial cost. Another disturbing factor is the recent suspicion that the *T. gambiense* strain, which causes sleeping sickness in West Africa, may be closely related to *T. rhodiense*, the strain responsible for the virulent East African

form of the disease, and that the *rhodiense* strain may arise as a mutant from the general *T. brucei* population present in game animals.

Animal Trypanosomiasis

In natural populations, tsetse flies transmit trypanosomiasis between wildlife hosts in what McLennan refers to as the sylvatic cycle. Transmission to domestic animals occurs when livestock are introduced into an area where the disease is present. The disease can also be transmitted between domestic animals, or strains can be transferred back to wild animals and later reintroduced into domestic herds. If these strains have become drug resistant, they retain their resistance throughout the cycle of transmission (Gray and Roberts, 1971a, 1971b).

Unlike the human disease, animal trypanosomiasis is carried by nearly all tsetse species. However, the actual infection rate and severity of the disease is often related to the type of tsetse and the density of the population, as tsetse species vary in terms of feeding preference, infection rate and transmission capability (MacLennan, 1979). Low levels of infestation by the riverine species cause low levels of infection, even among highly susceptible exotic livestock breeds, while larger numbers of the same riverine species give rise to more severe trypanosomiasis problems (Jordan, 1961; Page, 1959). Generally, flies of the savanna group cause very serious disease problems, even when they are present in small numbers (Kirkby, 1963; Leeftang, 1975). Some members of the forest group also undoubtedly feed on cattle when they have the opportunity and can be effective carriers of the disease.

All mammalian species of domestic livestock are susceptible to trypanosomiasis, but their susceptibility to different strains of trypanosome varies, as shown in Table 16. Cattle, for instance, are highly susceptible to *T. congolense* and *T. vivax*, while pigs are subject to fatal outbreaks caused by *T. simiae*. There is also a wide variance in pathogenicity among different strains of trypanosome species. Within livestock species, susceptibility also varies significantly

between breeds: for example, the N'Dama and West African Shorthorn cattle breeds and the West African Dwarf breeds of pigs, horses, sheep and goats show a substantial degree of tolerance to the disease, compared with Zebu or European stock. Stress factors are also important determinants of susceptibility. Losses can take the form of rapid mortality or chronic debilitation which depresses production potential in terms of growth, meat, milk, fertility and draught power.

Table 16. Species of pathogenic trypanosomes and susceptible hosts^a

	Humans	Cattle	Sheep	Goats	Pigs
<i>T. gambiense</i>	+++	-	-	-	-
<i>T. rhodiense</i>	+++	-	-	-	-
<i>T. brucei</i>	-	+	+	++	±
<i>T. congolense</i>	-	+++	++	++	±
<i>T. equiperdum</i>	-	+	+	+	±
<i>T. evansi</i>	-	++	+	+	±
<i>T. simiae</i>	-	-	+	++	+++
<i>T. suis</i>	-	-	-	-	++
<i>T. uniforme</i>	-	++	++	++	-
<i>T. vivax</i>	-	+++	++	++	-

a. Pluses and minuses indicate degree of susceptibility.

Source: Stephen, in Mulligan (1970).

LIVESTOCK PRODUCTION STRATEGIES IN THE TSETSE-INFESTED ZONE

Transhumant and Semi-Settled Production

The traditional patterns of transhumance enable most livestock to avoid tsetse-infested areas at times of greatest risk. During the dry season, when

grazing and water resources in the north are depleted, the tsetse population in the infested areas retreats into the moister localities. Transhumant herdsmen are able to bring their animals slowly down into the subhumid zone, grazing on crop residues and manuring the farmers' fields along the way, to utilize the well-watered fodder resources of the subhumid grasslands. These herdsmen use their knowledge of the areas of greatest tsetse infestation to avoid trypanosomiasis risk, though this is not always possible and disease outbreaks occur which can be serious. The situation is particularly difficult in times of drought when movement options are restricted. At the beginning of the rains, the transhumants avoid further risk by returning to the northern areas as soon as water and pasture are sufficient. Thus, during the rainy season in the six northern states of Nigeria, 86% of the cattle are found on only 46% of the land, corresponding with the area which is free of tsetse or only lightly infested.

Farmers and pastoralists can also be found settled in areas of light riverine infestation. These producers accept limited levels of trypanosomiasis among their herds, and they may also move their animals short distances during the season of peak infestation. In Nigeria, levels of infection in these areas have also been reduced because transhumant herds which come down seasonally from the north are now less likely to be infected due to tsetse eradication programmes in their home areas. If serious disease incidence does occur, pastoralists are usually able to move away to safer locations. The White Fulani Zebu, which form the basis for most of these herds, also appear to have a small degree of tolerance to light trypanosome risk arising from low-level riverine tsetse infestation (MacLennan, 1979).

When cattle are trekked down to southern markets along traditional trade routes, areas of infestation often cannot be avoided and tsetse populations have built up in some places based on the constant food source available from the cattle passing through. This problem may be alleviated with the present general trend away from trekking in favour of transportation by lorry. In Nigeria, for example, in 1974, the control posts at Wawa, Kontagora and Yelwa reported a total of 65 185 cattle passing through on the hoof and 15 051 in lorries: by 1978, 80 911 were reported in lorries and only 5 939 on the hoof (Nigeria, Tsetse and Trypanosomiasis Division, 1978).

Production Based on Trypanotolerant Breeds

Small-scale livestock production is also carried out in the southern part of the subhumid zone based on the trypanotolerant N'Dama and West African Shorthorn cattle and West African Dwarf sheep and goats (Pagot in IEMVT, 1974). Large-scale ranches have also been operated successfully in Congo and Zaire based on introduced trypanotolerant cattle.

Trypanotolerance has been defined by an FAO expert consultation (1976) as:

a hereditary biological property which enables certain breeds, or certain individuals, to live normally in a naturally infected environment while carrying pathogenic trypanosomes without themselves showing any clinical signs of the disease.

Tolerance is not absolute: it can be broken down by stress factors such as exposure to other diseases, heavy parasite burdens, parturition, lactation, inadequate nutrition or hard work (Touré, 1977). There is evidence that trypanotolerant cattle may be more susceptible than other breeds to certain diseases, notably rinderpest, but they appear to have greater resistance to others, such as dermatophilosis. When infected with trypanosomiasis, trypanotolerant animals develop anaemia, and several authors have claimed that their growth and reproductive performance are lowered. However, at some N'Dama multiplication centres where high abortion and calf mortality rates were initially attributed to trypanosomiasis infection, closer investigation revealed that high levels of helminthiasis were also a factor.

The hereditary nature of trypanotolerance was demonstrated by Esuruoso (1977), based on observations of a trypanotolerant Muturu herd kept in Nigeria. A group of Muturu were kept in a tsetse-free area and later housed continuously in fly-proof accommodation in the rain forest, to prevent any trypanosomiasis infection. The second generation of this group was experimentally infected with *T. vivax*, along with a group of Zebu cattle. The clinical course of the disease and the haematological changes in both types of cattle were similar, but the Muturu survived the infection for a period twice as long as the Zebu, indicating an innate, though partial, ability to tolerate the disease.

One immediate constraint on the increased utilization of trypanotolerant livestock is the general shortage of breeding stock, however. The multiplication of trypanotolerant breeding stock needs to be carried out on a priority basis. Whenever trypanotolerant stock are introduced into a new environment, prophylactic drugs should be administered for a short period while the animals adjust to new trypanosome strains and levels of infestation. This strategy has been followed by extension programmes in several countries with good results.

Intensive Production with Susceptible Breeds

Livestock susceptible to trypanosomiasis are sometimes kept in the tsetse-infested zone under chemoprophylactic regimes. Such schemes have generally been undertaken in areas of dense settlement or on ranches where careful control of drug use is possible and where there has been a sufficient modification of the vegetation and fauna to make the area less inviting for resident tsetse populations. However, it has not proven possible to modify the environment sufficiently to make it totally uninfestable, since it is simply technically, financially and administratively impossible to exert comprehensive control of land use on the scale that would be required.

The problems are diverse. For one thing, all game reserves, national parks and forest reserves in the subhumid zone are almost certainly tsetse infested, and in several cases tsetse populations have advanced through these areas into pastoral grazing zones, agricultural areas or government stock farms (Wilson, 1958). For this reason, reforestation projects, even in the Sahel, should anticipate the need for tsetse-control measures. In Nigeria north of Bauchi, for example, an integrated agricultural project was initiated for settled Fulani who practised stall feeding and used oxen for ploughing. A *G. morsitans* population which occupied a nearby forest reserve spread to the pastures, causing a major trypanosomiasis outbreak which could not be contained by trypanocidal drug treatment alone. Several examples of this type of problem have occurred elsewhere in the subhumid zone.

A second type of problem has occurred in a number of areas apparently free of savanna tsetse infestation, but where the introduction of cattle has resulted in an incidence of trypanosomiasis. In these cases, the disease problem brought to light tsetse populations, originally too small to be detected, which were able to escalate rapidly with the new food supply. It appears that a penumbra of flies exists around a tsetse-infested area which is very difficult to detect. Given this penumbra, no susceptible livestock are safe within several miles of a primary tsetse focus. Either a nearby tsetse population may advance into the livestock production area or a small number of local flies may increase rapidly in response to the new source of food (Leeftang, 1975; MacLennan in IEMVT, 1974). In either case, satellite tsetse populations can become established and an intense transmission cycle rapidly escalates, causing serious losses in spite of treatment with trypanocidal drugs.

An example of this situation arose at the government livestock farm at Shika, in Nigeria, at the northern limit of the subhumid zone. Initial surveys before the farm was established did not reveal any *G. morsitans* infestation. The farm functioned successfully for a number of years, and then *T. vivax* was discovered as the cause of high abortion rates. This signalled the outbreak of a serious trypanosomiasis problem. Though few flies were ever detected, they were later found breeding on the farm in an atypical habitat (Kirkby, 1963).

Another example arose with the beef fattening operation which was set up at Mokwa Ranch, also in Nigeria, in an area of heavy tsetse infestation. The herd was maintained under prophylactic treatment and animals were not grazed within 0.8 km of the ranch boundary. However, because of poor pasture management, trees and shrubs encroached on portions of the ranch, and a reinfestation of tsetse led to a serious incidence of trypanosomiasis when the ranch veterinarian went on leave and treatment was relaxed. Similar advances of the tsetse population have also led to serious disease problems along traditional cattle trek routes (Baldry, 1969b; Ferguson, 1964b; Riordan, 1971; Yesufu and Mshelbwala, 1973).

Domestic pigs are sometimes kept in tsetse-infested areas. They appear to tolerate relatively mild infections of *T. congolense* and *T. brucei*, but if *T. simai*

is introduced through infected flies, a fatal outbreak is likely, even though the overall tsetse population is extremely small (Baldry, 1964).

If draught oxen are introduced onto farms in the tsetse-infested zone, heavy losses can result. Where small numbers of oxen are widely dispersed over a number of holdings, prompt treatment is difficult to organize, leading in some cases to drug resistance, anaemia and myocarditis. However, in other parts of the sub-humid zone, for instance in northern Benin, the use of draught oxen has increased substantially without tsetse control measures and without serious losses. Much depends on the degree of risk from tsetse, the breed of animal, and husbandry and stress factors.

This variety of experience points to the need for more precise information on tsetse populations and a clearer demarcation of the areas where control measures are necessary.

TECHNIQUES FOR THE CONTROL OR PREVENTION OF ANIMAL TRYPANOSOMIASIS

When considering the various approaches to a trypanosomiasis problem in a particular area, a basic distinction must be made between eradication and control objectives. In a control situation, measures are taken against the disease and/or the vectors in a defined area within a zone of infestation. While the initial costs may be limited, control involves vector and disease surveillance on a continuous basis, with a substantial technical and supervisory commitment. An eradication programme, by contrast, involves the elimination over a larger area of the tsetse population which carries the disease. Once the vectors are eliminated, a tsetse-free status is maintained. Either an entire tsetse belt is eliminated or a large area is treated which can subsequently be protected with a minimum of financial and technical resources. A special issue is raised in many cases where the area of infestation crosses national boundaries. In these instances, the most effective approach to eradication would call for international cooperation on a regional basis.

After a substantial eradication operation has been carried out, the surveillance and supervision requirements become less over time, limited to the vulnerable perimeter of the eradication zone if the entire local tsetse belt has not been eliminated. However, this type of operation can only be undertaken in situations where it is technically feasible and within the limits of available funds. Such a programme must be based on detailed knowledge of the local tsetse distribution and habitat relationships and requires a substantial field capability.

The nature of tsetse distribution and reproduction makes eradication possible over large areas of the drier savanna zone. Present levels of knowledge and technology are now being developed to make possible the extension of eradication programmes into the moister areas. Where eradication is still not technically or financially feasible, control measures must be accepted, though production based on susceptible livestock with prophylactic treatment is usually not feasible except in areas of relatively low risk and where treatment can be rigidly controlled, as the experiences already described demonstrate. Production based on trypanotolerant livestock is another possibility.

Of the range of techniques available or being developed, some are more appropriate for eradication operations and some more appropriate for control. Many techniques are used for both types of operation, applied on different scales and in different infestation circumstances.

Habitat Modification

Bush Clearing. Bush clearing was the main technique used to control riverine tsetse populations in the campaigns to suppress sleeping sickness before the advent of modern insecticides. Methods vary from complete removal of the woody and shrub vegetation, known as sheer clearing, to selective clearing of only that vegetation known to be important to the survival of a particular tsetse species. Selective clearing becomes more difficult in humid environments where the tree cover is dense (Keay, 1953) and the fly population less dependent on particular types of trees

or shrubs (Davies, 1964; MacLennan, 1967; MacLennan and Na'isa, 1971).

Early clearing campaigns were carried out by hand, but more recently mechanized methods have been introduced involving the use of bulldozers and drag chains. Clearing operations carried out with motorized saws and arboricides have been disappointing. In all cases, the major problems have been the physical control of rapid regenerative growth and the costs of both the initial clearing and the control of regrowth, which requires continuous supervision and countermeasures.

The technical problems and, more importantly, the high costs of these operations are only justified in particular circumstances, such as when limited clearing is required along rivers to control sleeping sickness or when a barrier strip is cleared along the perimeter of a tsetse eradication area or an intensive livestock development project. Because of the cost, clearing is usually limited to a one-mile-wide (1.6 km) strip, usually accompanied by periodic applications of insecticide along both sides or only along the infested side of the cleared area.

Large-scale clearing might be justified when coupled with a programme of intensive land use, involving the development of arable or mixed farming or intensive ranching with improved fodder production and appropriate stocking rates to prevent the reinvasion of trees and shrubs. However, in Africa this approach has seldom proved economic in terms of beef production, although, in Latin America for example, it can be economically attractive provided the land to be cleared has sufficiently high agricultural potential. Even in such cases, however, the area covered is likely to be small in terms of overall livestock production needs and the size of the tsetse-infested zone.

Wildlife Elimination. Control of tsetse populations by eliminating their wildlife hosts has been attempted mainly in eastern Africa, and especially in Uganda (Wood, 1968). In Nigeria, along the Jama'ara Katagum River, warthog shooting and trapping were encouraged in the early 1960s as a measure to control the *G. morsitans* population (Davies, 1964). The operation was apparently successful, though mainly

through the use of insecticides. Game eviction is likely to be used in future only in exceptional circumstances, due to organizational difficulties and the pressure of world environmental opinion.

Housing. Under zero-grazing systems, susceptible livestock can be protected from trypanosomiasis risk by keeping them in fly-proof shelters. This might be practicable and economically feasible in the case of intensive dairying or pig production in the tsetse-infested zone (MacLennan, 1979).

Chemotherapy and Prophylaxis

A small number of curative and prophylactic drugs have been developed and are widely used in Africa for the treatment of animal trypanosomiasis. The same drugs are often used for both curative and prophylactic treatment: the distinction lies in the quantity of the dose and sometimes in the form of administration. A drug may be administered curatively at three to five times the level of the prophylactic dosage.

Drugs most often used for prophylaxis and treatment are listed in Tables 17 and 18. Novidium was the first to be developed, but by about 1964 strains of trypanosomes were appearing which were resistant to this drug. Berenil was introduced at that time, but again resistance developed quickly. A few other products have been introduced since then, but drug resistance and cross-resistance are becoming an increasingly serious problem. In spite of this, the commercial pharmaceutical firms have not developed any new drugs for some time. This type of research and testing work involves substantial investments, and the potential African market is perhaps not sufficiently attractive to justify, from a strictly commercial point of view, the level of expenditure required. The Tsetse and Trypanosomiasis Division of the Nigerian Federal Livestock Department has been actively involved in testing trypanocidal drugs and is carrying out research on the mechanisms of drug resistance.

Table 17. Trypanocidal drugs used for prophylactic treatment of domestic livestock

Name of Drug	Trade Name	Trypanosomes Affected	Length of Protection	Treatment of Relapses
Isometamidium chloride	Samorin	<i>T. vivax</i>	2-4 months	Diminazene
	Trypamidium	<i>T. congolense</i> <i>T. brucei</i>		
Pyrithidium bromide	Prothidium	<i>T. vivax</i>	2-4 months	Diminazene
		<i>T. congolense</i>		Isometamidium
Quinapyramine chloride and sulfate	Antrycide	<i>T. brucei</i>	2 months	Suramin
	Prosalt	<i>T. evansi</i>		
Suramin-quina-pyramine complex		<i>T. simiae</i>	young pigs:	Isometamidium
		<i>T. evansi</i>	3 months	
			adult pigs: 6 months	Isometamidium Diminazene

Source: FAO (1979a).

Several livestock production projects have been carried out in tsetse-infested areas under chemoprophylactic drug regimes. This type of operation has been successful in areas where the level of tsetse infestation is sufficiently low, but it is not recommended under high infestation conditions. With medium infestation, it has been found that a high level of management and veterinary and entomological supervision is essential to avoid major disease outbreaks or a general increase in drug-resistance. The timing and dosage of the drug regime must be strictly adhered to and blood samples must be examined on a regular basis, requiring a degree of simple laboratory support. It has been the usual experience that block treatment of an entire herd at appropriate intervals gives better results than waiting for an individual positive diagnosis, because in cases where prophylaxis is waning infection may occur before it becomes detectable by blood slide examination (MacLennan, 1979).

Table 18. Trypanocidal drugs used for curative treatment of domestic livestock

Name of Drug	Trade Name	Trypanosomes Affected	Treatment of Relapses
Homidium bromide	Ethidium	<i>T. vivax</i> <i>T. congolense</i>	Diminazene Isometamidium
Homidium chloride	Novidium	<i>T. vivax</i> <i>T. congolense</i>	Diminazene Isometamidium
Diminazene aceturate	Berenil	<i>T. congolense</i> <i>T. vivax</i> (<i>T. brucei</i>) (<i>T. evansi</i>)	Isometamidium
Quinapyramine sulfate	Antrycide sulfate	<i>T. congolense</i> <i>T. vivax</i> <i>T. brucei</i> <i>T. evansi</i>	Isometamidium
Isometamidium chloride	Samorin Trypamidium	<i>T. vivax</i> <i>T. congolense</i> (<i>T. brucei</i>)	Diminazene
Suramin		<i>T. evansi</i> <i>T. brucei</i>	Quinapyramine

Source: FAO (1979a).

This situation greatly favours the development of drug-resistant strains. A different drug should be introduced when curative treatment becomes necessary, but even this may not always be effective because by now cross-resistance to several trypanocides has become a widespread phenomenon. In some cases, reinfection has been detected only 10 days after treatment with a prophylactic.

The costs of carrying out such programmes and the risks involved often mean that livestock projects based on chemoprophylactic treatment become unecon-

omic. It has been estimated that the total costs of the management, veterinary supervision and services required may amount to 10 times the cost of the drugs alone, and, perhaps more importantly, the type of personnel and the supervision required is not widely available in developing countries.

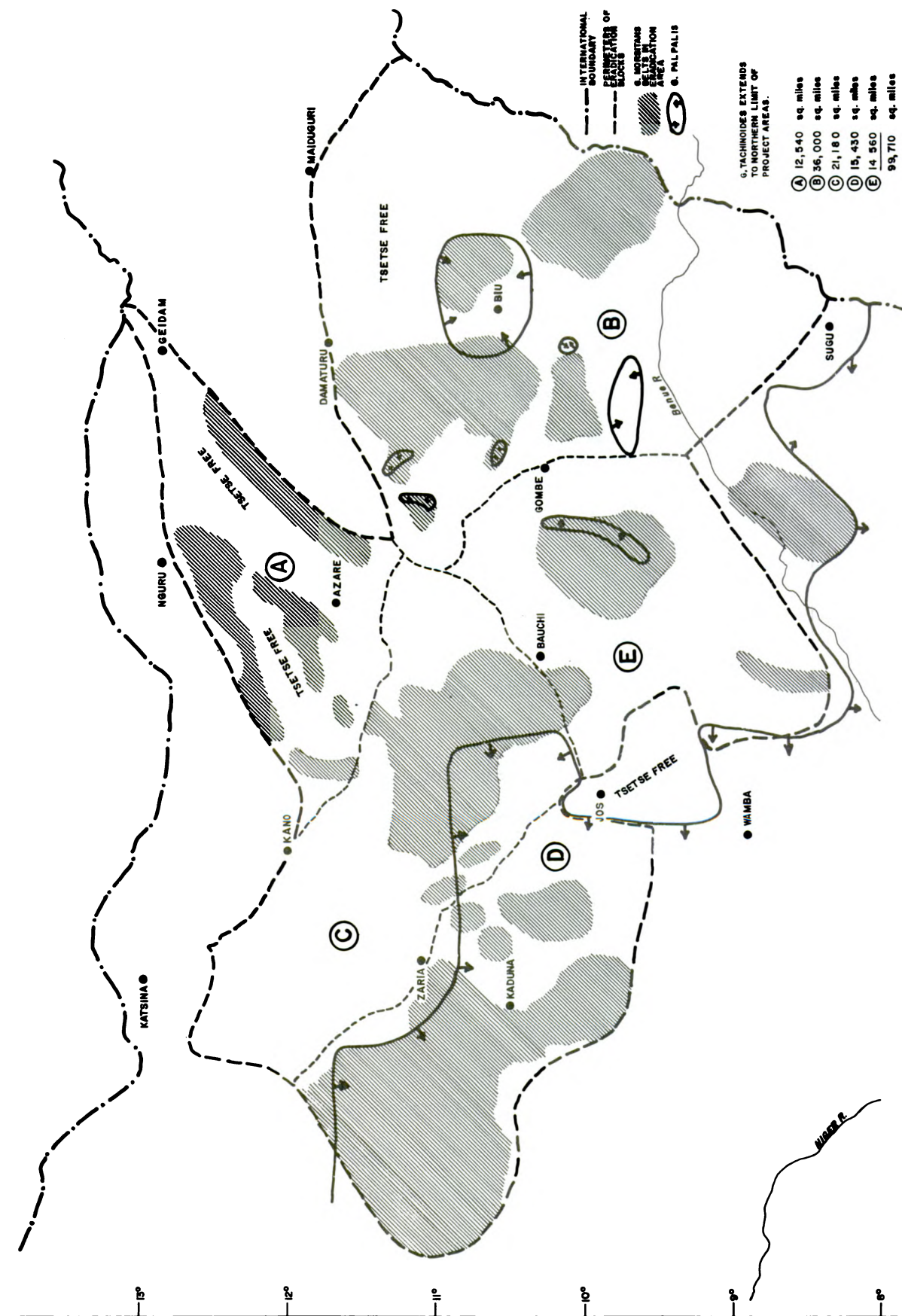
The problems of treating transhumant herds or draught animals widely dispersed on small farms are even greater. In many countries, the demand for trypanocidal drugs far exceeds the capacity of the official distribution system, resulting in the widespread illicit use of drugs. In such a situation, it is impossible to ensure that the drugs are properly administered, and the use of drugs at sub-curative levels or the use of the wrong drug or dosage for the particular situation has contributed to the sharp increase in drug-resistance. Breakdown resulting in serious disease episodes is not unusual, even on projects with high levels of management.

The use of trypanocidal drugs has been more successful in situations where treatment has been of limited duration, for example when cattle must be trekked through tsetse belts on the way to slaughter. These herds usually come from areas which are free of infection and may therefore have little or no resistance, particularly under the stress of travel; consequently they often suffer heavy losses. Since normally only a short period of protection is required, a properly supervised chemoprophylactic programme can be of great benefit in reducing losses. A similar argument in favour of prophylactic treatment can be made in the case of feedlot operations.

Insecticide Spraying

Spraying programmes involve placing lethal doses of insecticide on trees or shrubs where tsetse flies rest or in the atmosphere where they fly. A number of different methods have been developed, and extensive eradication programmes based on spraying have been carried out in Nigeria, as shown in Figure 7. As of 1977-78, a total of 204 802 km² had been cleared in that country, including 190 232 km² by

Figure 7. Tsetse eradication blocks in Nigeria



Source: Na'isa (1979).

ground spraying units, 12 366 km² by helicopter and 2 204 km² by fixed-wing aircraft.

In the francophone countries, programmes have usually been more modest so far and in most cases are still at the experimental stage, for example in Senegal, Mali, Chad and the Central African Empire (Finelle, 1964; Gruvel et al., 1970; Tibayrenc, 1977; Touré, 1973). Some of this work is particularly interesting because it has focused on the precise distribution of resting riverine species, allowing very selective insecticidal treatment. For example, a radio-marking technique has been described for detecting flies resting during the day time (Laveissière, 1976; Laveissière et al., 1978; Challier, 1973; Bois et al., 1977; Challier et al., 1978b).

Spraying programmes may be classified according to the method of application, for instance from a team walking along the ground with knapsack sprayers, from helicopters or from fixed-wing aircraft. The duration of the effects of the spray also vary, from transient or non-persistent to persistent or residual formulations. In addition, the areas treated vary: with selective spraying, only certain patches or groups of vegetation are sprayed and only those parts of the plants which the flies are known to frequent, but with non-selective spraying wide swaths of vegetation are covered. A variety of equipment and insecticides is available, suited to different circumstances. These are described in detail in FAO's *Insecticides and application equipment for tsetse control* (1977e).

Ground Spraying with Residual Insecticides. This method involves a single placement of persistent insecticide on the preferred tsetse resting places (Davies, 1964; MacLennan, 1967). The insecticide remains lethal for about eight weeks until all the pupae in the ground have hatched. To achieve this degree of persistence, relatively heavy rates of application are required, but the application is very selective, based on detailed knowledge of the ecology of the target species in each particular area, as preferred resting places vary considerably among tsetse species and in different climatic zones (MacLennan, 1967; MacLennan and Cook, 1972; Scholtz et al., 1976).

Spraying is done at the end of the dry season when the flies' habitat is somewhat reduced. Swaths may be sprayed on either side of streams or at intervals of about 150 m in dense woodland. In savanna areas, small habitat features may be sprayed, such as individual trees or thickets. Large teams of labourers are required, with supervisory personnel, and a network of camps, tracks and access paths must be constructed. Although the necessary level of organizational and logistical support is considerable, this type of operation brings secondary benefits to the local community in terms of employment and increased access to remote areas - indeed, a high proportion of total expenditure remains in local hands.

This approach has proven highly successful in eradicating both savanna and riverine tsetse species in the drier areas to the north of the subhumid zone. It has also been successful, though more difficult and more expensive, in the less densely wooded parts of the subhumid zone itself (see Keay, 1953). In moister environments with denser vegetation, the tsetse habitats become more diffuse and difficult to recognize and a larger proportion of the vegetation must be sprayed to achieve eradication (MacLennan and Na'isa, 1971). The method is technically and financially efficient if only 10% of the vegetation has to be sprayed, but if more than about 18% of an area must be covered, costs escalate and there is greater concern about the environmental side effects. Moister climatic conditions also reduce the period of effective persistence of the insecticide. In areas of dense settlement in the moister areas, however, the tsetse's resting places may be reduced by bush clearing, farming and intensive grazing. In such circumstances, selective ground spraying may be an effective means of eradicating tsetse, though it will probably be more useful as a control technique.

Helicopter Spraying with Residual Insecticides. Persistent insecticide is sprayed selectively on preferred tsetse habitats from small, low-flying helicopters. As with ground spraying, detailed knowledge of the local tsetse habitats is important, and considerable logistical support is needed to clear a number of small temporary landing places, to service and maintain the helicopters in the field, to carry out tsetse surveys both before and after spraying and to provide protection against reinvasion.

This approach has been made feasible by the development of ultra low volume insecticide formulations and spray equipment specially designed for use on helicopters (Lee, 1977; Spielberger et al., 1977). Droplet size and the rotation speeds of the atomizers used for distributing the spray are of crucial importance because deposits must be large enough to be lethal, numerous enough to give adequate coverage and heavy enough to penetrate the tree canopy from the air. This technique is also very sensitive to meteorological conditions. As with ground spraying, it is more effective during the dry season; in addition, windy conditions must be avoided. A condition of temperature inversion must exist, where ground temperatures are lower than those at, say, 7 m, because, when the lower air is warmed by the sun, turbulence develops which can carry small droplets upwards and away from the target areas. Spraying is thus restricted to short periods around dawn and dusk.

The helicopter is flown one or two metres above the tree canopy at speeds of 32 to 40 kph over savanna country. The speed is reduced over forests to give a down draught strong enough to disperse the insecticide below the trees. Insecticide is sprayed along linear swaths oriented according to preferred tsetse habitats, as with ground spraying. If the operation proceeds smoothly in areas where only 10% of the vegetation must be covered, a unit of two helicopters can spray about 3 600 km² in one season. Though much less logistical support is needed than for ground spraying, the cost of the helicopter can more than offset the savings on labour and transport.

Compared with ground spraying, larger amounts of insecticides are required since spraying within the swaths is much less selective. As a result, the impact on non-target organisms is substantially greater (Koeman et al., 1978). The costs and environmental effects also rise considerably if more than a certain percentage of the area must be sprayed: as with ground spraying, the upper limit is probably about 18%. This means that, although the technique has proven effective in eradicating riverine and savanna tsetse populations in the northern subhumid and Sudanian zones, it becomes less effective in more humid regions.

Non-Residual Insecticide Spraying from Fixed-Wing Aircraft. This technique shows promise for application in moister areas, though as yet only limited trials have

been conducted in the subhumid zone (Lee, 1977). Exceedingly small doses (6–12 g/ha) of non-residual insecticide are sprayed into the air over an entire area, killing all adult tsetse as they fly. Applications are repeated, usually about five or six times at 10- to 19-day intervals over a period of about two months. This should be sufficient to kill all the flies emerging from pupae before they have a chance to deposit pupae themselves. Knowledge of the timing of the tsetse reproductive cycle is of crucial importance, as this varies in each local area according to prevailing temperatures (Glasgow in Mulligan, 1970; Phelps and Burrows, 1969).

Usually, a rectangular area is sprayed along flight lines about 300 metres apart, oriented transversely to the prevailing wind. The aircraft flies about 7 m above the tree canopy, closely controlled by personnel on the ground. A very high standard of navigation is required, calling for an experienced pilot and sophisticated navigation and emission control equipment. Meteorological conditions are even more critical than with helicopter spraying, but over flat terrain spraying can be carried out at night. However, if only a single aircraft is available, the operation becomes highly vulnerable to delays resulting from equipment failure, and if a delay between application goes beyond the period of the tsetse reproductive cycle, the whole series of operations must be repeated.

As with helicopter spraying, the formulation of the insecticide and the rate of emission are crucially important. An attractive feature of this technique is the low dosage of insecticide required, which keeps costs and environmental side-effects at a minimum.

Insecticide Formulations and Environmental Effects. Over the years, only DDT and dieldrin have proven effective in eradicating tsetse by ground spraying operations (Lycklama and Nijeholt, 1965; MacLennan, 1967). Of the two, DDT has extremely long-lasting effects on tsetse populations in drier areas and is less toxic to humans, but dieldrin is more effective in the denser habitats of the more humid regions (Koeman et al., 1971). For helicopter spraying, special ultra low volume formulations of dieldrin and endosulphan are used, and endosulphan concentrates are used for fixed-wing spraying operations.

In Nigeria, a number of studies have been carried out on the environmental effects of tsetse eradication operations (Koeman and Pennings, 1970; Davies, 1964; Koeman et al., 1971). Ground and helicopter spraying with dieldrin and endosulphan causes heavy mortality rates among fish, frogs, reptiles, insectivorous birds, fruit bats and one type of monkey at the time of spraying. However, tsetse elimination is largely achieved by a single application, and the readiness with which these species return to an area which has been sprayed depends on the distance of the nearest neighbouring population and whether the habitat is substantially changed, for example by land clearing and the introduction of cultivation, after the eradication campaign (FAO, 1977f; Koeman et al., 1971). Apart from some elevated residual levels among frogs, studies conducted one year after spraying found very little insecticide remaining, indicating that any serious long-term accumulation problem is unlikely. In areas visited nine years after ground spraying with dieldrin and DDT, all bird and fish species previously affected had returned in substantial numbers (MacLennan, 1973).

These studies indicate that ground spraying, which is more discriminative, has fewer side-effects than helicopter spraying (Koeman et al., 1978), and that dieldrin is more damaging to birds and mammals, while fish and reptiles are more susceptible to endosulphan. It is possible to reduce the environmental effects of spraying in many situations by using a combination of methods and insecticides: this approach is already being followed in Nigeria. Environmental effects can also be minimized by spraying particularly vulnerable habitats, such as fringe forests around streams, from the ground, rather than from helicopters.

Studies have been carried out elsewhere in Africa on the environmental effects of non-residual endosulphan spraying from fixed-wing aircraft (Wood and Turner, 1975). It was reported that no serious side-effects occurred, but there is little information on the effects of this technique in the subhumid zone. The very low levels of insecticide used suggest that environmental side-effects may not be too severe

Over the years, a number of other insecticide formulations have been tested, including organophosphorous and carbamate compounds, but they have proved less effective in eradicating tsetse flies than the insecticides already in use and have shown similar adverse environmental effects. Recently, small-scale tests have been conducted involving ground and helicopter spraying with synthetic pyrethroids, and the results have been encouraging (Challier et al., 1978a). The different pyrethroid compounds tested proved highly toxic to tsetse with relatively few side-effects, though crustaceans and some other insects were affected. Extremely low dosage levels are required. Further testing is now being carried out by the Nigerian Tsetse and Trypanosomiasis Division to identify improved formulations with reduced repellent effects and increased persistence.

Other Techniques

Sterile Male Release. This technique involves releasing large numbers of male tsetse flies which have been sterilized by radiation or exposure to chemicals. Because the female tsetse apparently mate only once, if the sterile males reach them before the males in the natural population they will not reproduce.

This method may prove effective in eliminating small residual tsetse foci which are often difficult to detect or to eradicate by conventional methods (Jordan, 1976). If large populations are involved, the majority must be eliminated first by spraying with non-residual insecticides. To be effective, the sterilized males have to outnumber the natural male population by at least 3 to 1.

At present, breeding colonies to produce a sufficient number of sterilized males are expensive and difficult to maintain. If more than one species of tsetse is to be controlled, separate breeding colonies have to be established for each species. Though there are also some doubts as to whether artificially reared males can compete successfully with natural males in terms of survival and mating ability, cultured males from irradiated pupae have been shown in some tests to be fully competitive.

Trials have been carried out at Bobo Dioulasso in Upper Volta and at Tanga in Tanzania. At Bobo Dioulasso, production of 20 000 sterilized males a month is envisaged (Itard, 1974), whilst in Tanzania 6 500 sterile male *G. morsitans* were released weekly over an area of 100 km². Consequent on the development of an effective chemical attractant, it is possible to envisage large-scale field trapping and automatic sterilization and release which would circumvent the difficulties encountered with colonization.

Attractants. The effectiveness of all tsetse eradication methods would be greatly enhanced if local fly populations could be brought together in one place through the use of long-range olfactory attractants. More accurate survey and detection would be possible, spraying operations could be concentrated in smaller areas, and other methods, such as the release of sterile males, would become economically feasible. Work is being carried out in this field and, though no readily available practical attractant has been developed as yet, some promising advances have been made.

Techniques Still at the Experimental Stage. Growth regulating hormones have been identified which affect, for example, the maturation of the tsetse puparium (Mouchet, 1974). Research is also being conducted on tsetse control through the use of larvacides (Jordan and Trewern, 1978), sterile hybrids, tsetse parasites and viral and bacterial diseases which affect the flies (Laird, 1977). Cattle dipping or spraying against ticks has been shown to have a limited effect on tsetse.

The search for a trypanosomiasis vaccine is being carried out at the International Laboratory for Research on Animal Diseases (ILRAD) in Nairobi. Although this would be a most attractive solution; it is made difficult by the number and variability of trypanosome antigens. However, recent work at ILRAD and elsewhere has opened up several promising avenues of research in this area, giving an indication that an immunological solution is not as impossible as was once thought (Murray et al., 1979).

In the francophone countries, a biconical tsetse trap has been designed which should not be too difficult or expensive to construct. The most successful design developed so far is a device with a blue lower cone (Challier and Laveissière 1973). In Ivory Coast, blue cloth screens impregnated with an insecticide, decame-thrine, have been used experimentally on cocoa and coffee plantations, and preliminary results are promising. In areas with a small local tsetse population, the regular use of traps could have a significant effect because the flies are not very prolific.

ECONOMIC ASSESSMENT OF TRYPANOSOMIASIS ERADICATION AND CONTROL PROGRAMMES

It is difficult to quantify the economic losses attributable to animal trypanosomiasis, though these are no doubt substantial. It is likely that most of the direct economic losses are incurred by pastoralists who are forced to bring their herds through infested areas, mainly on transhumance or on the way to market, or who suffer a low but constant level of losses in areas of light riverine infestation. Devastating losses can also occur when tsetse of the savanna type advance into an area where livestock are kept by local producers or on government stock farms.

Trypanosomiasis also has a significant effect on the viability of livestock development projects. Many of these projects are economically marginal, and the considerable expenses of surveillance, management and treatment of infected animals and/or vector control can be enough to make a livestock project show a loss.

More important than actual mortality rates or production losses, however, is the loss of production potential of the abundant fodder resources in areas which are not fully utilized because livestock cannot be maintained on a permanent basis. The presence of savanna tsetse not only prevents the utilization of valuable fodder resources directly, but when the flies infest strategic locations, such as around water sources, grazing in extensive adjacent areas becomes hazardous.

These underutilized land resources in the subhumid zone are becoming increasingly valuable as the human population expands, resulting in a sharply increasing demand for land and meat and milk products. The relatively sparsely populated areas of the subhumid zone have assumed particular importance as a destination for immigrant settlers from the overpopulated humid zone to the south and Sudanian zone to the north.

At the same time, population pressure and the extension of cultivation in the Sahelian and Sudanian regions have pushed traditional livestock producers more deeply into the tsetse-infested areas for longer periods of time, resulting in greater animal losses.

In Nigeria, the problem of competition for land became acute in the 1950s and led to the initiation of the present anti-tsetse programme. Tsetse clearance made possible the year-round utilization of grazing areas in the subhumid zone, relieving the pressure on ecologically fragile areas farther north which were being increasingly utilized for arable farming. It allowed many of the pastoralists to settle in subhumid areas and made it possible for the size of the national herd to remain stable in spite of increased pressure on grazing resources in large parts of the country and the effects of the Sahelian droughts.

Although crop production can take place in tsetse-infested areas without the introduction of livestock, the land resources in such a situation are often not exploited to their full potential. For one thing, the production increases obtainable from the use of animal draught power are foregone, and, to increase crop production substantially, mechanized farming must be introduced from the outset. Livestock and crop production tend to be mutually dependent. Farmers need livestock to supply them with meat and milk products and to renew the fertility of their fields with manure, while pastoralists need farmers as a market outlet and to provide them with both staple foods and crop residues which are an important source of forage for their livestock. Livestock also put to productive use the otherwise neglected grazing resources of the farming areas. Such an interrelationship between arable farming and livestock production, whether it occurs on one mixed holding or involves

a relationship between two groups of people, makes possible a more balanced and more productive use of the land. This is only feasible when an area is at least largely free of trypanosomiasis.

Costs of Eradication and Control Programmes

Information on costs is only available for the two tsetse eradication methods which have been used in West Africa on a fairly wide scale, the selective application of long-lasting insecticides by ground spraying and by helicopter. From the records of the Tsetse and Trypanosomiasis Division of the Nigerian Federal Livestock Department, it is possible to estimate the costs of ground spraying at ₦ 150 to 200 (US \$ 240 to 320) per km² while costs of helicopter spraying are about ₦ 250 (US \$ 400) per km². These costs can be broken down as shown in Table 19, though, as explained previously, they will vary according to ecological conditions and the scale of the operation.

Table 19. Breakdown of costs of tsetse eradication programmes

	Ground Spraying	Helicopter Spraying
Labour	38%	3%
Insecticides ^a	18%	36%
Flying time ^a	-	51%
Junior Staff	23%	3%
Senior Staff	16%	2%
Vehicles ^a	2%	2%
Depreciation ^a	3%	3%
Total	100%	100%

a. Imported items; the total foreign exchange component for ground spraying is 23%, for helicopter spraying 92%.

Source: Putt (1979).

To the costs of the original operation must be added those of a certain amount of respraying, say 20%, to ensure complete eradication. This brings the total costs of ground spraying up to ₦ 180 to 240 (US \$ 283 to 384) per km² and the total costs of helicopter spraying up to ₦ 300 (US\$ 480) per km². Then to these basic costs must be added a share of the other costs of running the Tsetse and Trypanosomiasis Division. These cover headquarters costs, off-season activities such as surveys, salaries of permanent staff outside the spraying periods and replacement costs for buildings, vehicles and equipment. These costs are relatively low for the helicopter unit because it is run with a small supervisory staff only, amounting to about 50% of the basic expenditure, bringing the total costs up to ₦ 375 (US \$ 600) per km². By contrast, the ground spray units employ considerable numbers of people and consequently require more substantial support services. The costs of this support probably doubles and may even treble the basic cost, bringing the total to somewhere on the order of ₦ 360 to ₦ 500 (US\$ 576 to 800) per km². These figures are only provisional: actual costs vary according to ecological conditions, as explained previously, and the scale of the operation.

From these figures it would appear that helicopter spraying is an attractive approach. However, 90% of the variable cost of the helicopter unit must be paid in foreign exchange. Furthermore, the figures presented here are based on the official exchange rate: if the real cost in naira of the helicopter operation were calculated, this would be almost double the figures quoted.

On the other hand, it has been estimated that when a livestock development project is carried out in a tsetse-infested area, the full costs of eradication contribute only 2 to 4% of the total investment costs, if these are limited to the provision of water supplies and animal health services. Where further investments are envisaged, the costs of tsetse eradication will only comprise 1 to 2% of the total investment (Jordan et al., 1977).

No precise information is available on the costs of tsetse control, as compared with eradication. It can be assumed that the initial costs are significantly lower, but the costs of control recur continuously over an indefinite period.

Similarly, the costs of prophylaxis and treatment with trypanocidal drugs have often been estimated based on the cost of the drugs alone, whereas information from Botswana suggests that the full costs of a treatment programme, including personnel and equipment, can range up to ten times the cost of the drugs administered (Negrin and MacLennan, 1977).

Benefits of Tsetse Eradication

The principal effects of tsetse eradication have been the spontaneous changes in land use which have resulted. Yet because these changes are also due to other factors, it is difficult to quantify to what extent they are attributable to tsetse eradication alone. Some of the changes which can be expressed in numerical terms might be:-

- increased population in the area due to immigration,
- increased agricultural production due to the introduction of animal draught power,
- increased carrying capacity, in terms of the additional fodder made available,
- increased livestock numbers and livestock production, and
- halting or reversing large-scale tsetse advances.

Since the benefits accrue in the years after the costs for tsetse eradication are incurred, they have to be discounted. Both the discount rate used and the assumptions about the time span over which incremental production is attributable to tsetse eradication are as important in determining the economics of an eradication programme as the costs and the benefits accruing in any one year. For this reason, it is difficult and misleading to generalize. Each situation requires careful analysis and elaboration of all the implicit and explicit assumptions involved. For example, if the cost of eradication is ₦ 500 per km² and the discount rate is 12% (at present value of 1 per annum: 5-year factor of 3.6950), then the minimum annual level of benefits which must accrue in five years to cover the costs of eradication are about ₦ 140/km² annually to break even.

8. LAND-USE AND DEVELOPMENT STRATEGIES *

Land-use and land-tenure systems in the subhumid zone are currently going through a period of rapid and far-reaching change. This situation has partly been induced by different types of government intervention, most notable in the form of tsetse eradication and the demarcation of grazing reserves, but it is much more the result of spontaneous development and change. The subhumid zone has long been a relatively empty belt between much more densely populated areas to the north and south. De Leeuw estimates that the subhumid zone could support a population density on the order of four people per km² based only on extensive cattle production, while the population density in the Sudanian zone to the north and the forest belt to the south is approximately 80 times this level. It is obvious that the future development of the zone will be influenced largely by increased immigration from these more populous areas and the present form of extensive land use will not be maintained.

Most of the people migrating into the subhumid zone are farmers, and well over half of the land is generally considered suitable for arable farming. All this arable land is expected to come under cultivation within the next 30 years in Nigeria and within 40 to 45 years in the other countries of the zone. Spontaneous settlement under increasing population pressure without adequate government planning and

* Based on papers presented by A T Malumfashi and M B Ajakaiye, as well as the papers which contributed to the previous chapters. Discussion in this area was led by S Sandford and summarized by D J Pratt and S Nuru.

control is likely to lead to the 'shifting cultivation trap'. Initially all goes well, with farmers cultivating parcels of land for two or three years until fertility falls, when new land is cleared, leaving the former cultivated fields to lie fallow for an extended period. While this lasts, it constitutes a viable production system, but as population increases, the fallow periods decrease until pressure on the land reaches a point where cultivation becomes continuous without any fallow period at all. Land tenure then becomes fixed under the control of individual farm households whose holdings seldom exceeding five ha. At this point, it is very difficult to initiate a mixed farming system with properly integrated crop and livestock production, designated to maintain fertility by rotational grazing and cropping and the use of farmyard manure. Ideally, for mixed farming with adequate feed for livestock, holdings of at least 15 ha are required.

Incursion by farmers also has major implications for the future of extensive livestock production in the zone. The increasing occupation of arable land by sedentary farmers has already disrupted traditional pastoralists' transhumance patterns in many areas. The result is that livestock production is pushed back into areas unsuitable for agriculture or combined with crop production in various types of sedentary mixed farming systems.

It is inevitable that mobile pastoralism, as it now exists in the subhumid zone, will progressively decline. The process of sedentarization has already been underway for some time among the Fulani in Nigeria. Baxter (1976) and many other authorities suggest that most pastoralists would settle willingly if a sedentary life could be achieved without detriment to their stock and their subsistence needs. On the other hand, it appears that full sedentarization will be preceded in most areas by a protracted period of semi-sedentary livestock production. Many of the pastoralists already maintain a 'home base' at the northern end of their transhumant circuit where some family members remain throughout the year and where in many cases some cultivation is practised. A strategy towards more intensive production in the subhumid zone could begin with efforts to encourage these semi-sedentary pastoralists to transfer their home base and the associated cropping activity to the higher rainfall areas. Their best interests in the future are generally seen to lie

in the direction of at least partial settlement, with formalized land tenure rights and closer linkages with government development agencies. Possibilities for intensified production also exist in the form of smallholder breeding and fattening enterprises, large-scale ranches, commercial feedlots, improved dairying and mixed farming enterprises.

At least one observer (Frantz, 1975) has noted the modifying effect of recent demographic, economic, political and legal changes on traditional pastoralism in Nigeria. Frantz has directed attention to the need for further demarcation of grazing and farming areas, migration controls, improvements in marketing, range management and commercial ranching. He has predicted that land rights will become increasingly formalized, with continued incorporation of pastoralists into the national economic and political system. In his view, the future of pastoral groups in Nigeria will be problematic unless permanent local groupings are formed and systems of individual or corporate land tenure developed.

In planning the overall development of the subhumid zone, government agencies need to pursue a variety of objectives concurrently. From the ecological point of view, development planners must think in terms of maintaining the long-term productivity of entire countries, rather than considering the various ecological zones in isolation. The economic objectives of an intensified livestock production programme include the provision of an improved standard of living for traditional livestock producers and an increased supply of meat and milk to the population as a whole. The equity implications of development activities must also be taken into account. Care should be taken to identify the poorer members of the pastoralist community and to assure that their interests are not neglected. In traditional pastoralist societies, the stronger, wealthier community members tend to look after the weaker, but reliance cannot be placed entirely on these safeguards when initiating a process of far-reaching social and economic change.

Conflicts of interest between different members of a pastoralist society may be exacerbated in the process of development. For example, at present the pastoralist system is geared primarily towards milk production, with meat produced

generally as a by-product. Decisions on the consumption and sale of milk are often made by women, while the decision to slaughter or sell an animal is more likely made by a man. For this reason, a shift in emphasis towards meat production might have serious repercussions for pastoralist family life. However, if development is seen as a general increase in livestock productivity through improved management and animal feeding, then the shift in emphasis towards commercial meat production should occur gradually without serious social disruption.

Development planning in the subhumid zone must also never lose sight of the important relationship between the transhumant pastoralists and the settled agricultural communities. Neither the pastoralists nor the farmers are self-sufficient in terms of food production: the pastoralists depend on the farmers for purchased grain to supplement their diets, and the farmers depend on the pastoralists for the animal products necessary to assure them an adequate protein intake. Moreover, a substantial proportion of the fodder provided to grazing animals during the early part of the dry season consists of crop residues available on the farmers' fields after the harvest, while the fertility of these fields is enhanced by the manure left by the passing herds. Already, the availability of chemical fertilizers has disrupted this symbiotic relationship to some extent, and farmers in some areas have even started charging the pastoralists for access to their crop residues. The collection of a cattle head tax (*jangali* in Nigeria) also affects the relationship between farmer and pastoralist, as a portion of the funds collected is generally allocated to the local settled communities. Some observers in Nigeria have reported that with the recent waiving of this tax the local communities have become less hospitable to the pastoralists in their areas.

With increased population pressure and intensified competition for land, clashes of interest between the traditional pastoralist and agricultural communities are likely to increase. Where such clashes have occurred, it has been the general experience that the pastoralists are pushed into the less productive areas and are generally left behind in the development process. The cattle Fulani in Nigeria, who own at least 90% of the national herd, are a small minority group, constantly displaced by the land requirements of a growing population of cultivators. Pastoralists

probably never comprise more than 10% of the population in any of the administrative areas where they occur.

The establishment of commercial ranches or others forms of intensive enterprises may also lead to competition with traditional producers for government attention and development funds. Offtake rates on commercial ranches may be relatively high, but traditional production systems support more people and may have higher ecological efficiency in terms of energy production and conservation.

In the present situation, development planning must be accompanied by a broadly based implementation programme. In addition to protection from trypanosomiasis and the demarcation of grazing reserves, government involvement must include the establishment of animal production support services, equipped with the necessary technical capacity to facilitate the transition from traditional to more intensive - though not necessarily highly intensive - production systems. These would include expanded veterinary services, watering and stock handling facilities, an improved processing and marketing system, and medical, educational and other social services for the livestock producers. The major question is whether such services can be designed and implemented quickly enough to match the pace and scale of spontaneous settlement and intensified land use.

The technical information available in the fields of animal health, nutrition and fodder production is already adequate as a basis for intensified livestock production, but experience is limited concerning how to translate this technical knowledge into viable programmes in the field. There has been a general failure to integrate social and economic aspects with technical improvements. Efforts to improve traditional production should start with a thorough understanding of the practises and perceptions of the pastoralists, as well as their aspirations and production environment. Furthermore, development programmes, once they are underway, should proceed by incremental steps, involving at every stage a two-way exchange between the traditional producers and the planners and technical advisors and a broadly shared responsibility for decision making. The basic premise

behind such development efforts is that change in the system is unavoidable. Traditional pastoralists have always responded flexibly to changing circumstances as a matter of necessity; however, with increasing demographic pressure from outside the zone, the rate of change has accelerated substantially and the choice now lies between planned development and haphazard colonization and exploitation of the savanna areas, which could ultimately lead to social, economic and ecological deterioration.

GRAZING RESERVES AND DEVELOPMENT BLOCKS: A CASE STUDY FROM NIGERIA

By the early 1960s it was already evident that the pastoralists of the sub-humid zone in Nigeria were gradually being pushed out of the more densely populated areas. Some of them were even migrating permanently to the neighbouring countries of Cameroon, Chad and Niger. On the assumption that the pastoralists required five or six ha of rangeland per animal unit to sustain their animals throughout the year, the former Government of Northern Nigeria drew up legislation, reserving areas permanently and solely for grazing. The Minister of Animal and Forest Resources, who introduced the legislation, justified this strategy as follows:

... It will enable my Ministry and the Native Authorities to create Grazing Reserves so that the grazing rights of cattle-owners can be fully protected by law. This will also help to reduce the friction between cattle-owners and farmers which has in the past led to bloodshed and loss of life. Moreover, it will be possible to carry out pasture improvement work in the legally constituted Grazing Reserves by planting different types of grasses, and permanent supplies of water can be provided. In this way the number of animals that can be kept on the same area of land can be greatly increased. This kind of improvement work cannot be undertaken now because the pastures are open to all and are usually burnt every year for hunting or other purposes to the degradation and detriment of the pastures.

Another benefit which the creation of Grazing Reserves will bring is the gradual settlement of the nomads. This will make it possible for their children to be educated, and for them to obtain regular health services. Economic benefits will accrue to them through the regular marketing of their milk and other dairy products. They can even form cooperative

societies to market their cattle in properly constituted markets so that they are not cheated by cattle traders who at present offer them very low prices for their cattle. In this way they can get a fair deal which will lead to an improvement in their living standards. This [legislation] will have tremendous effect on the development of our livestock industry and it will do justice to an important but non-vocal section of our community who in the past have been somewhat neglected.

The legislation was passed in 1965, but since then only a very small area has actually been established as grazing reserves, and, though measures are still needed to hasten the development of pastoralist livestock production, there is now considerable doubt as to whether the establishment of grazing reserves is the most sensible approach. By and large, proposals for pasture improvement have not been carried out, so it is difficult to assess what the potential benefits might be. The social services proposed for the pastoralists have also generally not materialized. At the Symposium an opinion was expressed that the establishment and development costs of the grazing reserves appear to be too high to justify them in economic terms: capital costs have been estimated at US\$ 128 per head of cattle grazed, and recurrent costs add about another US\$ 69 annually. At Nweri Grazing Reserve, these figures were US\$ 136 and US\$ 46. This means that the total cost of establishing and developing a grazing reserve averages about US\$32 per ha and that, with a stocking rate of 5 ha per tropical livestock unit (250 kg), the cost of keeping livestock on a grazing reserve comes to US \$ 160 per livestock unit. However, the annual productivity of a grazing reserve is estimated at only US\$ 32 per unit. To justify these reserves economically (taking into account operating and opportunity costs), a minimum development package must be designed which would cost on the order of US\$ 16 per animal unit, i.e. 50% of projected animal productivity.

Since the production potential of most of the subhumid zone will best be served under a system of arable farming, it would not seem to be in the national interest, or in the interest of the pastoralists, to reserve an unreasonably large amount of land permanently and exclusively for grazing. The grazing requirements of the present pastoral herd under an extensive production system have been estimated at 35 million ha in Nigeria, which is about 37% of the land area of the whole country. As population pressure increases in the zone, no government will be

able to resist the demands from in-migrating agriculturalists for arable land, and the Fulani themselves are also likely to take up farming to some extent. Wherever pastoralists settle, cropping is likely to become an important part of their production system, and eventually most of the subhumid zone is likely to come under some form of mixed farming, with local land use patterns determined by available resources, regardless of the ethnic or occupational backgrounds of the residents. It has even been suggested that, in a context of mixed farming, former agriculturalists may become more successful livestock producers than former pastoralists: Pullan (1978) has found evidence of this in Nigeria on the Jos plateau.

Furthermore, the permanent establishment of pastoralist herds in grazing reserves may not be the best grazing strategy to take advantage of the fodder resources of the subhumid zone. Some pattern of seasonal migration, though eventually on a reduced scale, is likely to be an appropriate permanent feature of livestock production in the region. In developed countries, such as Australia and the USA, and even in intensively cultivated agricultural areas such as central and southern India, transhumance is still practised to utilize fodder resources available in different areas at different times of the year. Pastoralists also prefer to graze their animals near villages at least during certain seasons, in order to sell milk and buy grain from the farmers and to graze their animals on crop residues after the harvests. This traditional pattern would mitigate against their willingness to settle on large grazing reserves intended for livestock production only. Possibly grazing 'corridors' might be a better alternative to grazing reserves, to facilitate transhumance as more of the subhumid zone comes under cultivation, with water, grazing and perhaps conserved forage and road transport facilities made available to the livestock producers.

One alternative to grazing reserves already envisaged is the demarcation and planning of development blocks on the basis of mixed land use, embracing existing cultivated land, grazing land which could be brought under cultivation and land which is suited only to grazing. Facilities would be provided, such as health, education and other social services, markets and water, and livestock production would be based on a combination of seasonal grazing, crop residues and pasture leys.

The development blocks could be linked with grazing reserves, which would cater for the larger resident or migratory herds and could also provide the basis for commercial ranch development.

For proper land-use planning, surveys are needed to identify the areas most suitable for various activities, from mixed farming to commercial ranching. At least 20 ha plots should be allocated to households for cropping and livestock production. However, with increasing population pressure, the planned development of these areas must proceed more quickly than it has in the past. To avoid unnecessary delays, entire blocks can be put aside for future in-migrants, or parts of blocks can be settled with some space reserved for additional farmers and pastoralists who will come later. The development block should be able to serve as a sufficiently flexible planning model for the gradual intensification of land use, and present grazing reserves could be assimilated into the new system, also accommodating a variety of land uses where appropriate.

DEVELOPMENT REQUIREMENTS

Land Allocation

The allocation of land to agricultural and pastoral households must be carried out with care, because the weakest members of the community, such as widows, the elderly and the dispossessed, are likely to be those least able to cope with complicated registration procedures. Especially if the development blocks come to be viewed as successful, the wealthier and more sophisticated households will be likely to take a disproportionately large share of the available land. It may also prove to be more efficient to focus land allocation and development efforts on households or groups which have already shown a propensity to settle.

The specific question must be resolved of how to identify and negotiate with pastoralist groups, if land rights are not to be allocated to pastoralists arbitrarily or solely on an individual basis. It is generally assumed that the allocation of land

ownership to pastoralists will encourage better management and eventual settlement, but it is not so easy in any particular situation to determine on what basis land rights should be allocated, both because the social system is complex and because the interests of neighbouring farmers need to be considered.

Once allocated, title deeds can be used as a basis for development loans. Ownership does not have to be allocated on an individual basis in order to attract loans; in Kenya loans have been allocated to pastoralist communities on the basis of title deeds issued to registered groups. Although some types of development might be financed by government grants, it is usually better if capital for development can be raised from local people within an area, rather than relying heavily on outside credit. Rural savings and credit institutions, often not well developed in West Africa, may need to be established for this purpose.

Current land tenure systems vary widely through the subhumid zone. In northern Nigeria, traditional occupancy has been based on land use. Any area which is not currently under cultivation is available for grazing and, similarly, pastoralist camps which have been vacated may be cultivated by farmers the following season. Village chiefs are generally responsible for seeing that the two forms of land use do not clash. When pastoralists settle with their herds, the land they use for grazing is allocated to them after several years, though it may be reallocated if they leave and it is not used for 13 years. This type of land acquisition implies acceptance of the pastoralists by the local sedentary population and the acquiescence of the local chiefs who are traditionally responsible for the disposition of land. In some cases, pastoralists have bought land from local farmers and resold it when they moved away.

Recently, a Federal Land Tenure Decree has provided a common form of land tenure throughout Nigeria. All land is now held in trust by the Federal Government, with control delegated to the State Governments and the Local Government Councils. The potential impact of this legislation on land tenure patterns in the subhumid zone remains to be seen.

In Senegal, traditional land tenure patterns are very complex, to enable pastoralist households to leave family members with parts of the herd scattered over wide areas to avoid disease, maximize grazing resources and protect their territory against outside incursions. More recently, there has been a trend towards at least partial settlement, with some crop production. The Senegalese government has divided the rural areas into local communities represented by elected leaders. A system of land reform has been introduced, whereby all land has been nationalized and then allocated to productive users, and the government is now in the process of demarcating grazing land and allocating it to groups of pastoralists in consultation with the local people. Experience has shown the futility of trying to impose radically different production systems on the local population; for example, an area designated for a major groundnut production scheme 20 years ago has reverted to mixed subsistence farming and livestock production. Efforts are now being made to group people into local communities with a minimum of disruption, with land-use patterns accepted willingly, rather than forced.

Government Services

Once land has been allocated, government agencies should concentrate first on the supply of inputs, strategic infrastructure such as communications and security, and marketing and other social services. Governments have been active in the range areas of several countries in cattle inoculation campaigns, the provision of water supplies and the implementation of tsetse control and eradication programmes. These are more basic and more profitable activities than trying to impose improved land use practices, such as rotational grazing, or to police herd size. Efforts in several African countries to control land use in this way have resulted in failure. However, this is not to say that advice on improved production practises should not be communicated through extension workers and the mass media, and intensified production projects initiated as a demonstration to local producers.

It should be kept in mind that governments have very limited financial and managerial resources: effective development packages should be designed which require a minimum of 'management' or government inputs, and implementation should be transferred to community organizations wherever feasible. The bulk of the resources and effort required for development will have to come from the local people, and development efforts will only be successful if active cooperation is ensured. Two examples of successful livestock development in Africa are relevant: the smallholder dairy sector in Kenya and the use of animal traction for cultivation in parts of francophone West Africa. In both cases, successful development efforts were based on self-sustained community participation with little or no direct input from government.

Pastoralist communities should be organized to manage communal services, such as fencing and water supplies, either through traditional institutions or through the formation of cooperatives with effective but equitable decision-making powers. The best form of community organization needs to be identified in each location, but care must always be taken to avoid a situation where the wealthiest or most sophisticated individuals are making decisions without some form of community control.

Strategies for Increased Cattle Production

In the traditional sector, which accounts for virtually all cattle production in the subhumid zone, the annual yield of weaned calf is probably less than 35 kg per cow and herd offtake rates are rarely over 7 or 8%. There is not likely to be any substantial improvement in productivity as long as calves are produced from unsupplemented cows which are also milked. Either it is necessary to encourage settled pastoralists to engage in dairy-oriented mixed farming based on improved systems of animal feeding which would raise productivity sufficiently to ensure an increased supply of both milk and meat, or pastoralists could be encouraged to pursue intensified forms of livestock production on group or cooperative ranches. The

financial aspects of these types of ranching enterprises in Kenya have been described and evaluated by Simpson (1973).

The alternative of regarding the present livestock owners simply as a source of young stock, to be purchased and finished by others, should not be discarded, though this approach seems hardly in the best interests of the pastoralists. In Nigeria north of the subhumid zone, some farming communities have been purchasing immature cattle from pastoralist producers for some time and stall feeding them on crop residues and the lower leaves of cereal plants stripped before harvest. This practice gives the farmers an additional outlet for investment and source of income and provides manure to fertilize their crops. This system also has potential for substantial expansion. Ranches specializing in beef production can be developed on similar lines, with or without the direct participation of the pastoralists.

A number of countries in the region have already established such ranches, often as government enterprises. Although these ranches may develop their own breeding herds, they are often largely dependent on purchasing immature cattle raised by traditional producers on economically marginal land which can then be finished on better pastures and supplementary feed. The viability of these ranches depends on a reliable supply of relatively cheap immature cattle, inexpensive sources of supplementary feed and sufficiently high producer prices for meat. Operating costs are usually high, including capital investments, such as fencing, water, buildings and breeding stock, and recurrent costs, such as management and labour fees, the purchase of immatures and supplementary feed and the amortization of capital investment. The supply of immature cattle at a reasonable cost poses a major constraint because traditional producers are usually reluctant to sell young stock in normal years unless the price is high. In the past, there has been considerable movement of trade cattle from the semi-arid zone in the north across national boundaries, but the exporting countries are now beginning to limit this movement of live animals in favour of establishing their own meat export trade. In view of these problems and the economic drawbacks innate in most government-managed ventures, it is doubtful whether government ranches will be able to contribute substantially to national beef production in the foreseeable future.

Feedlots have also been established in several places within the subhumid zone. These are intensive fattening operations where cattle - usually immatures - are kept in close quarters and fed rations rich in energy and protein. The animals are usually sold at the end of a period of 90 to 120 days. Feedlots are normally located near a source of relatively cheap animal feed but, even so, capital costs are high, and a dependable supply of suitable animals is essential. Even when all these production requirements are met, market prices and government policies will still determine the viability of any feedlot operation.

Marketing

The livestock marketing systems of West Africa have not been thoroughly documented. Private traders are reluctant to give information on producer prices or profit margins, though the studies which have been carried out suggest that the profits earned by middlemen are reasonable and that private marketing systems are fairly efficient. Nevertheless, livestock producers often believe that they receive low prices for their animals from private traders. On the other hand, government intervention through the creation of livestock marketing boards has generally not been noticeably more successful.

The introduction of intensified production systems will inevitably require improved marketing. In particular, a stratified market, offering higher prices for higher quality meat, would serve to encourage intensified production and an efficient stratified production system, with immatures from the northern areas fattened on ranches or feedlots located in the subhumid zone.

Extension Services

Extension services have been set up in most West African countries, but implementation in the field has been restricted due to the limited resources avail-

able, the large areas to be covered and the special difficulties involved in reaching migratory producers. Agricultural extension services were initiated in Nigeria in 1921 with the formation of a unified Department of Agriculture, and veterinary services started up in 1924 when the Veterinary Laboratories at Vom began producing hyperimmune rinderpest serum. Animal husbandry extension services were initiated much more recently with the creation of the Agricultural Extension and Research Liaison Service (AERLS) in the 1970s, as part of the Institute for Agricultural Research at Zaria. However, comprehensive extension coverage would require a substantially enlarged staff and close cooperation with other government agencies involved in the livestock production sector.

An example of the role of the AERLS is provided by their operations in the Samaru area. A Livestock Assistant was posted to the area, animal health care was offered to the pastoralists through the Faculty of Veterinary Medicine of Ahmadu Bello University, the local water supply was improved and cotton seed was provided as supplementary feed for sale during the dry season. The local Fulani formed a society which raised more than US\$ 8 000 a year to pay for supplementary feed, while the AERLS arranged for the purchase of the cotton seed through the Cotton Marketing Board and for transport. The Fulani came freely to the Livestock Assistant for help and advice, not only for problems connected with their livestock but also concerning the welfare of their families (Yazidu, 1978). The programme eventually experienced setbacks because funds were not available from the Kaduna State Government for the construction of more dams and disputes arose between the pastoralists and the local farmers. It also proved difficult to recruit additional extension staff.

The success of the inoculation campaigns carried out by the animal health services in Nigeria and elsewhere suggests that extension services will be well received by traditional livestock producers if they offer clearly demonstrable benefits. Such services should involve the establishment of demonstration centres, visits by extension staff and effective use of the mass media. Additional extension staff must be recruited and incentives provided to motivate them to work in the rural areas. In addition to more attractive salaries and working conditions, they

need adequate transport facilities if they are to visit producers scattered over a wide area. Staff development and training programmes must also be provided and field work must be carefully planned and supervised.

A special issue involved in efforts to reach traditional livestock producers is the head tax on cattle imposed in many West African countries. This tax (*jangali*) was waived in Nigeria in 1975, where it was argued that the tax hindered the close cooperation of pastoralists with government extension workers. An unexpected effect has been a worsening of the relationship between village chiefs and the Fulani pastoralists who are no longer seen as contributing to local government expenses. Further study is required to identify ways in which livestock producers can contribute to government revenue on a fair and equitable basis without reducing the supply of marketed meat and milk or discouraging them from taking advantage of extension and other government services.

9. DIRECTIONS FOR FURTHER RESEARCH

Livestock production in the subhumid zone is based almost entirely on pastoralist systems which are traditionally transhumant, but increasingly tending towards sedentarization. The zone is relatively sparsely populated and the potential for increased livestock production is considerable in spite of a number of production constraints. Due to increasing population pressure in the semi-arid areas to the north and the coastal belt to the south, immigration into the subhumid zone is substantial, leading to increasing cultivation and eventual pressure on traditional grazing land. In this situation careful development planning and prompt implementation are the only alternatives to haphazard settlement and the possibility of inappropriate or inequitable land use.

Two types of development are envisaged within the zone. On arable land, mixed farming systems can be developed with integrated livestock and crop production. In these areas, increases in productivity will be achieved through a balanced form of land use on holdings of viable size under a secure tenure system. In areas which are too dry or otherwise unsuitable for cropping, livestock production will continue to be based primarily on natural pastures, with a gradually increasing emphasis on meat production.

During the course of the Symposium, several topics were identified which require further research to provide a basis for livestock development in the subhumid zone. Although in many cases technical information is available which could

lead to increased livestock production, not enough is known about present production systems or how innovations can be adapted and applied to local conditions. The research requirements discussed during the Symposium can be classified as information needed to understand existing production systems more fully and information needed to formulate strategies for improving production.

PRESENT PRODUCTION SYSTEMS

A number of specific research needs were brought out during the Symposium related to pasture resources and management. The monitoring of rangeland vegetation was called for, together with assessment of the yield potentials of major rangeland types under different management systems and grazing intensities. The major tools available to traditional livestock producers for pasture maintenance and improvement are grazing and burning, and an assessment of different grazing strategies and the use of fire at different times of year was called for. Particular attention should also be paid to the browse species which provide a valuable forage supply during the dry season when grazing is scarce.

Basic information on the livestock production system of the pastoralists is also inadequate. For one thing, only very approximate estimates have been made of the human and livestock populations. Little information is available on the size or structure of pastoralist herds and flocks, on production parameters such as birth rates, growth curves, lactation yields, disease incidence and mortality, or on management factors such as breeding strategies, seasonal movements, offtake and sales. Clearly, it is difficult to plan or carry out appropriate development programmes when so little is known about the potentials and constraints of the production systems which are to be developed. The factors behind present low levels of productivity need to be analysed, particularly the interacting roles of inadequate nutrition and the incidence of disease. The levels of protein, energy and minerals actually available to grazing animals at different seasons have only been estimated, and little is known about the relative importance of different diseases and the

seasonality of disease incidence. Among cattle diseases, the importance of sub-acute trypanosomiasis needs to be investigated, particularly as a factor leading to poor reproductive performance, and further research is needed on the epidemiology of dermatophilosis, the incidence of *Theileria* and the disease relationships of the most important tick species.

Information on sheep and goat production is particularly inadequate; more needs to be known about small ruminant management systems, including nutrition and health factors. In particular, the importance of *peste de petits ruminants* (PPR) needs to be assessed, as well as strategies for its control.

More precise information is also required on present tsetse populations so that areas may be demarcated more clearly in which control measures will be a prerequisite to expanded livestock production. Present studies of trypanotolerant livestock breeds should be continued and coordinated, evaluating the performance of these animals under different management and tsetse challenge conditions.

Questions were also raised during the Symposium concerning the effect of cattle tax on offtake rates and on the receptiveness of pastoralist producers to government development efforts. An investigation was also called for of the factors leading to the current high offtake of female cattle reported in various northern markets. Finally, the economics of present livestock production systems need to be better understood, including a more accurate assessment of the land, labour and capital assets available to transhumant and sedentary producers.

IMPROVED PRODUCTION SYSTEMS

In formulating strategies for improving livestock production in the subhumid zone, the requirements and aspirations of the livestock producers must be assessed. The nutritional requirements of the pastoralists and the herd sizes required to meet their basic needs are only partially understood, and very little is known of the

development preferences and goals of the pastoralists and small farmers of the zone. Their attitudes towards sedentarization, herd size, structure and offtake rates, arable farming and various pasture improvement strategies need to be assessed before any interventions can be contemplated in these areas.

Strategies for increasing livestock production may focus on integrated systems of animal production and arable farming, on the development of large-scale commercial ranches, on a tiered production system involving the purchase of immatures from pastoralist producers for finishing on ranches or feedlots, or on a combination of these approaches. These alternatives need to be analysed in terms of economic feasibility and social impact. In particular, the economics of beef and milk production should be compared, and the role of small ruminants evaluated.

Under all these systems, the improvement of dry-season forage is likely to be a crucial factor in efforts to increase livestock production. In addition, several management innovations need to be assessed, such as early weaning, selective breeding, night grazing and various animal health interventions.

Integrated farming systems should include pasture leys in the crop rotation to replace natural fallows. Promising grass-legume mixtures for this purpose need to be identified, along with suitable methods of establishment and management, including techniques for seeding on untilled land. Improved cropping practises also need to be evaluated, both in terms of increased yields and the output of residues suitable for animal feeding. The cost-effective use of supplementary feeds needs to be investigated, particularly focussing on possibilities for the increased use of local byproducts. Efforts to develop integrated farming systems should include strategies for increasing both milk and meat production and sales and the use of animal traction for crop production.

Specific research needs related to the development of large-scale commercial ranches in the subhumid zone include the development and testing of cost-effective methods of mechanized bush-clearing and seedbed tillage.

The direct establishment of improved pastures needs to be compared in economic terms with the establishment of pastures following two or three years of cropping. The feasibility of tiered production systems also requires further investigation.

Based on the production systems to be encouraged, land-tenure and land-use policies need to be formulated which will provide a stable basis for development. The Nigerian experience with grazing reserves was discussed during the Symposium, as well as experiences in Kenya with different forms of individual and group ranching enterprises. A land-use strategy based on mixed development blocks was suggested, but further trials and investigation need to be carried out to identify the most appropriate land-tenure systems for specific areas.

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APPENDIX: SYMPOSIUM CALENDAR AND PARTICIPANTS

CALENDAR

Saturday 24 March	<u>Introduction</u>
a.m.	<p>Opening Address by the Honorable Commissioner for Animal and Forest Resources, Kaduna State, Alhaji B Mohamoud.</p> <p>Response by D J Pratt, Director of ILCA.</p> <p>Keynote Address by Prof S Nuru, Director of NAPRI.</p> <p>The ecology and economy of the subhumid zone, by A Blain Rains.</p> <p>Livestock production systems in the subhumid zone of Nigeria, by R von Kaufmann.</p>
p.m.	Free
Sunday 25 March	<u>Field Visits</u>
	<p>Visit to ILCA case study areas at Kachia Grazing Reserve and Abet.</p>
Monday 26 March	Visit to NAPRI headquarters at Shika.

Tuesday 27 March

Discussions

a.m.

Ecology and fodder resources: discussion led by R Rose Innes, based on background papers by P N de Leeuw and J C Bille (with supplementary paper by W Doppler).

p.m.

Livestock production and health: discussion led by D H Hill, based on background papers by W Ferguson and A A Ademosun (with supplementary paper by C Hoste).

Wednesday 28 March

a.m.

Tsetse and trypanosomiasis: discussion led by H E Jahnke, basen on background papers by K J R MacLennan and S N H Putt (with supplementary papers by B K Na'isa and S M Toure).

p.m.

Social aspects of livestock development and experiences of sedentarization: discussion led by C E Hopen, based on background papers by M Awogbade and J A Ekpere.

Thursday 29 March

Land-use administration and extension services for the pastoralists: discussion led by S Sandford, based on background papers by Alhaji Tijjani Malumfashi and M B Ajakaiye.

p.m.

Closing discussions, led by D J Pratt and S Nuru.

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